Control ENGINEERING

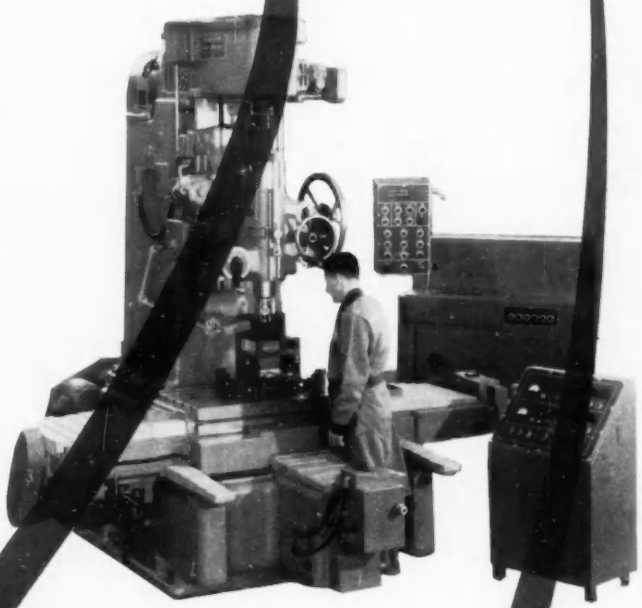
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

60 CENTS

APRIL 1958

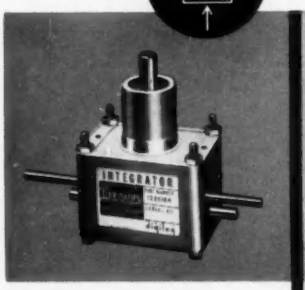
Reliability & Maintenance



Major Problems in Complex Control Systems

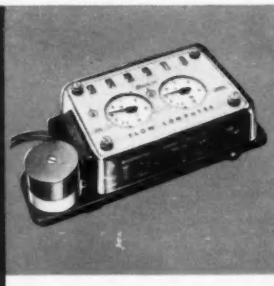
Computing Components / Instrumentation and Controls

BY LIBRASCOPE

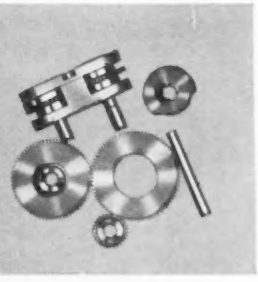


Ball-Disc Integrator... for use in totalizing, rate determination, differential analyzers, or as a closed loop servo-element... 0.01%V(av) optimum reproducibility.

Linear Integrator... for systems or instruments requiring integration, average computations, direct or remote reading... mounted on chart recorder.

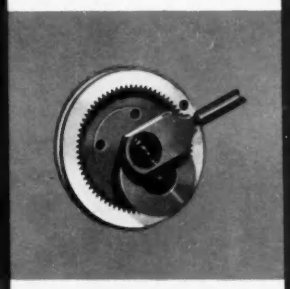


Flow Computer... extracts square root and continuously integrates both differential and static pressures for applications such as orifice measurement of fluids.

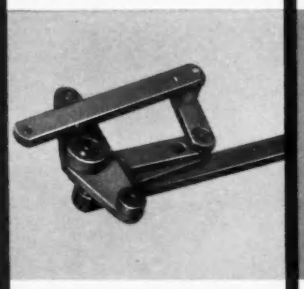


Custom Gears, Limit Stops, Shafts, Coupling and Cams... for computer, servomechanisms and instrument applications.

Analog Digital Converters... for converting shaft position to digital information available in Binary, Gray code or Binary decimal. Also Sine Cosine functions.

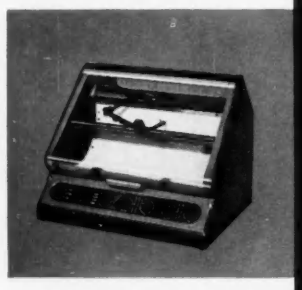


Sine Cosine Mechanism... for problems of changing variables involving vector components, range and bearing computations, sight computation, etc.



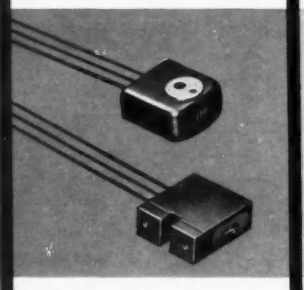
Linkages... for computing equipment; precision addition, subtraction linkages; multiplying linkages and function generators with displacement outputs.

Hollow Shaft Differential... offers greater versatility in summing angular shaft positions; Hollow Shaft reduces breadboard and production costs.

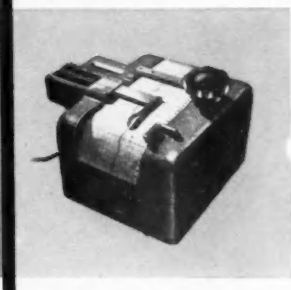


X-Y Plotter and Recorder... for point or continuous plotting, with positive mechanical drive in recording graphic data. Several models and accessories available.

Magnetic Storage Drum... for medium storage applications; capacity 131, 072 non-volatile bits; drum speed 3800 rpm; clock frequency 130 kc.



Read-Record Heads... for high frequency, non-contact recording applications in magnetic memory systems; high read back signals.



Planimeters... for miniature strip chart recorders for simple integration with variable speed control; 2 models: square root and linear.

There are available catalog sheets, bulletins or folders on all our products.

No. 50

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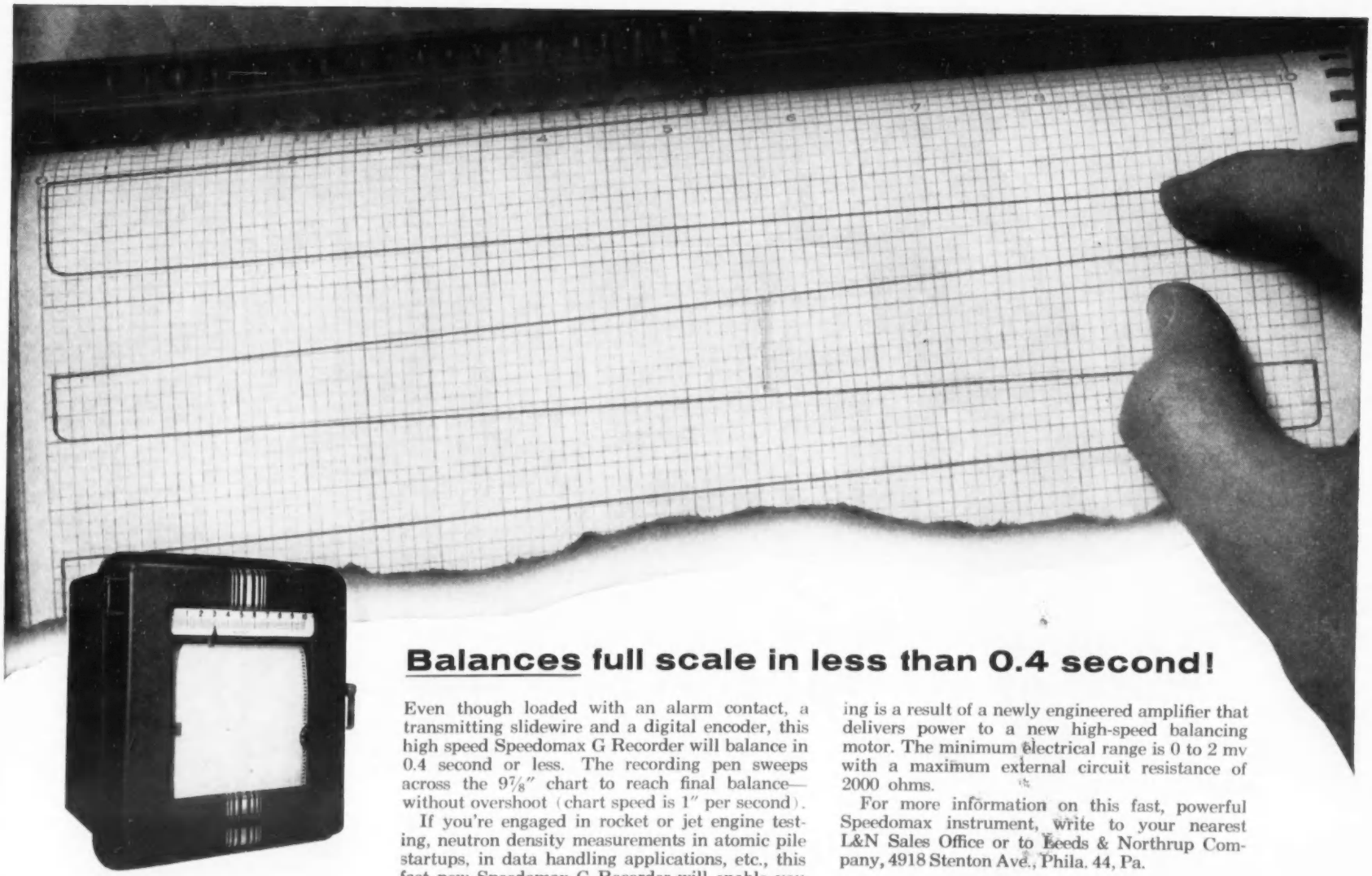

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Even though loaded with an alarm contact, a transmitting slidewire and a digital encoder, this high speed Speedomax G Recorder will balance in 0.4 second or less. The recording pen sweeps across the 9⅞" chart to reach final balance—without overshoot (chart speed is 1" per second).

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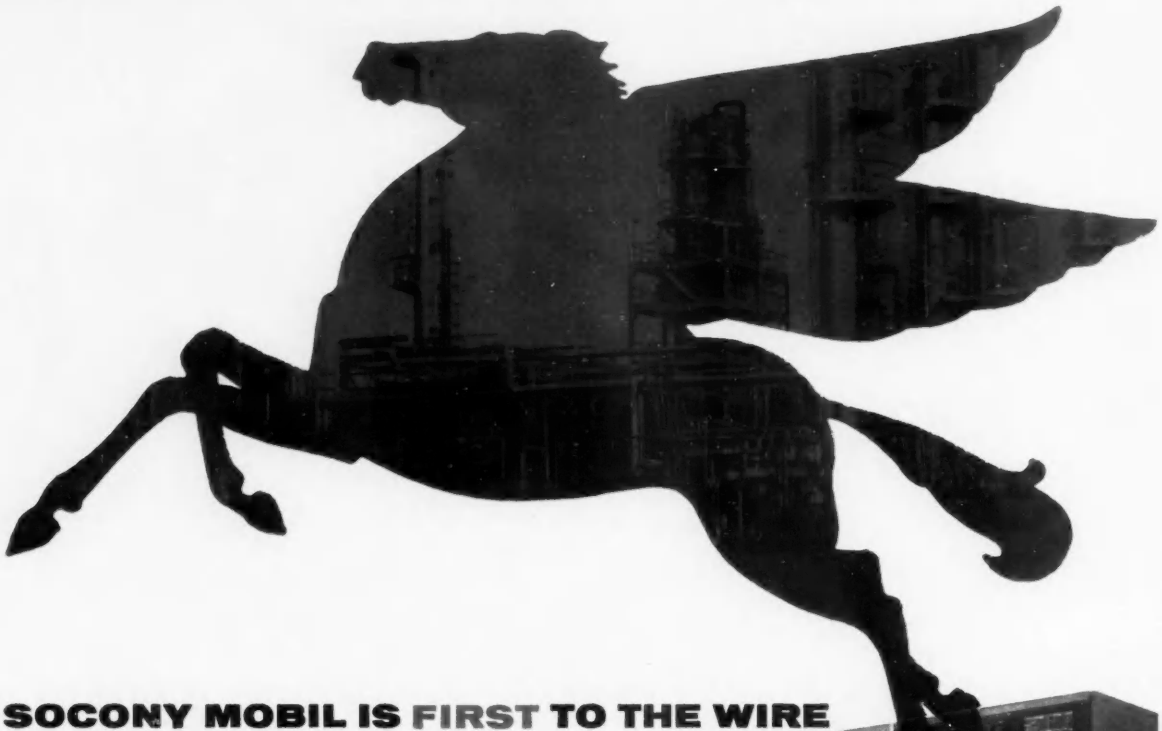

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with a major refining process chiefly dependent on an automatic data processing system...

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When Socony Mobil decided to add a new multi-million-dollar catalytic reforming unit to their existing plant at Casper, Wyoming, they played a systems favorite. They put their instrumentation money on Beckman Systems Division.

Going on-stream to push out 3,000 barrels of hi-octane a day, Socony Mobil couldn't take chances with an untried instrumentation system. And yet, because they were investing in the future, they couldn't afford to put their money on the past.

Socony Mobil's decision was obvious: they had to have the very latest in a data processing system without sacrificing old-fashioned reliability. Only one data system seemed to offer daring new design and solid-state circuitry backed up by hardware already system-tested and proved in on-stream operation... *It was the Beckman 112, designed and built for continuous, twenty-four-hour, seven-day-a-week service in the process industries.*

The Socony Mobil handicappers were so sure they had picked a winner that they decided to build the *first* major on-stream process unit with normal operations dependent on an automatic data system. The Beckman-Socony Mobil entry eliminates almost all of the expensive duplication of conventional, parallel, back-up recording instrumentation.

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Systems Division

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Control ENGINEERING

APRIL 1958
VOL. 5 NO. 4

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

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LOUIS A. EDELMAN, author of the instrument statistics article on page 86, is a prime example of self-determination. Forced by circumstances to switch to night school when he was 14, he went on to earn his high school diploma. In the midst of the depression he joined the U. S. Army Air Corps, advancing to the rank of captain before a physical disability forced his separation in 1948. At this point he decided that he needed a college educaton, and earned BA and MBA degrees in economics in the next three years. Then a return to government service led to his present position in the Dept. of Commerce. And, to top it all, at the age of 50 he's back attending night school again, working toward a PhD.

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Simpler, faster, more accurate setup of function generators

with the EASE push-button servo system*

BRIEF SPECIFICATIONS

Model 1171 Function Generator

OUTPUT—Voltage Y, within —100 to +100 V, varying in 20 straight-line segments which approximate the curve of the function, with a desired functional relationship to input voltage X.

ACCURACY — Error in setting breakpoint, 0.1% of full scale; error in setting output value, 0.05% of F.S.; diode rounding effect for 1:1 change in slope, 0.1% of F.S.

DRIFT — 0.03% of F.S. over any one-hour period; 0.07% per day.

Model 1172 Setup Unit

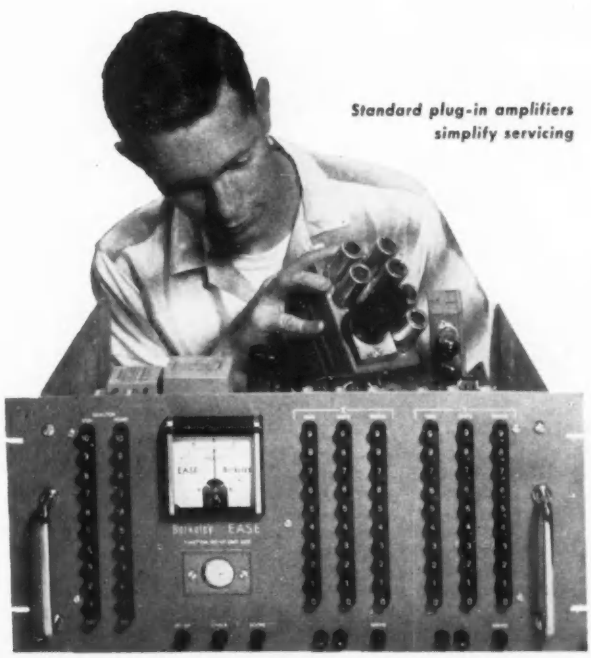
PURPOSE — Provides push-button setup with checking facilities. Contains servo amplifier, switching, precision input voltage, output reference divider, and metering.

ACCURACY — Nulling error ±.03% of full scale.

MOUNTING—Fits standard EASE* cabinet or any standard relay rack.

DIMENSIONS—Panel, 8¾" x 19"; depth 14¼" plus connectors.

(Typical values: full scale = 200 V)



Standard plug-in amplifiers simplify servicing

EASE* 1100 Series computers offer unmatched speed and accuracy with virtual elimination of operator error in setting up function generators. Consistent with the advanced "human engineering" concepts reflected in all design aspects of this series, precise and completely reliable control of setup is accomplished simply, without adjustment of knobs.

Up to ten Model 1171 variable base function generators are at the operator's fingertips through the Model 1172 push-button setup unit. It provides separate three-digit arrays of push buttons for setting X and Y values for each generator; a simple null checking method for verifying output over the entire range of inputs; a meter enabling the operator to trim the function, and a panel scope for visual monitoring of the function curve.

Model 1171 biased diode type generators approximate single-valued functions by means of line segments; locate breakpoints with three-place accuracy. Each generator incorporates two plug-in DC amplifiers of extremely high gain, high frequency response and superior stability.

The Series 1100 servo-setup function generator system uses Beckman/Berkeley's new no-drag clutches, which act independently of each other, disengage completely after setting, and have operational life exceeding that of the pots themselves. This advanced engineering achievement is instrumental in providing push-button control with accuracy of ±.03% nulling error full scale. For complete information on the Beckman/EASE* 1100 Series, which is upgrading design and performance standards in the analog computer field, write to Dept. **L4**.

Beckman® / ***EASE COMPUTERS***

Mfd. by Berkeley Division, Beckman Instruments, Inc. Richmond 3, California

153 *Trademark

EASE Computer service is available on a rental basis. For full details, write George I. Bekey, Director, Beckman/Berkeley Computation Center, 307 Parkman Ave., Los Angeles 5, California

SHOPTALK

Interpretation is our Job

Realizing that only a small percentage of CtE's 33,000 subscribers would be able to attend the recent Fourth National Reliability and Quality Control Symposium in Washington, D. C., a symposium of vital interest to them all, CtE editors Ed Kompass and Lew Young decided to bring it to you. They took in all the sessions, talked with the conferees, and then prepared the article appearing on page 105, which was written with the aim of pulling out of the mass of reliability data the information that is of significant interest to control engineers. One of the most interesting items brought to light was the new concept of "systems effectiveness", in which reliability is only one of many variables. Don't miss this roundup, tailored strictly for control engineers.

One chance in a thousand

That's about the odds for ever getting the entire CONTROL ENGINEERING editorial staff together at one time, what with Derek Barlow in Europe and one or two editors always on the road. But amazingly enough, at a recent editorial evaluation and planning meeting at the Scarsdale Golf Club, every staff member reported present. Standing, from the left: Will

Garey, publisher; John Cooney, associate editor; Warren Kayes, copy editor; and Art De Weerdt, circulation manager. Seated, from left to right, Jack Gordon, art director; By (no tie) Ledgerwood, managing editor; Lew Young, associate editor; Derek Barlow, European editor; Bill Vannah, editor; Flo Baxley, editorial assistant; Frank McPartland, assistant editor; Harry Karp, associate editor; and Ed Kompass, assistant editor.

Yes, we publish an index

Several readers have reported that they didn't realize we published a yearly index of CONTROL ENGINEERING's editorial material. Actually, each December issue contains an index for that year, and a limited number of reprints are available for those who would like a file copy (the 1957 index appeared on pages 185 to 194 of the December issue).

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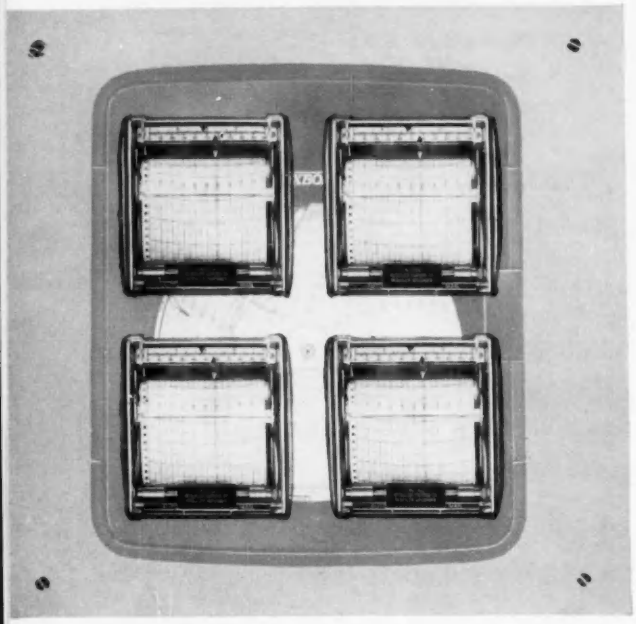
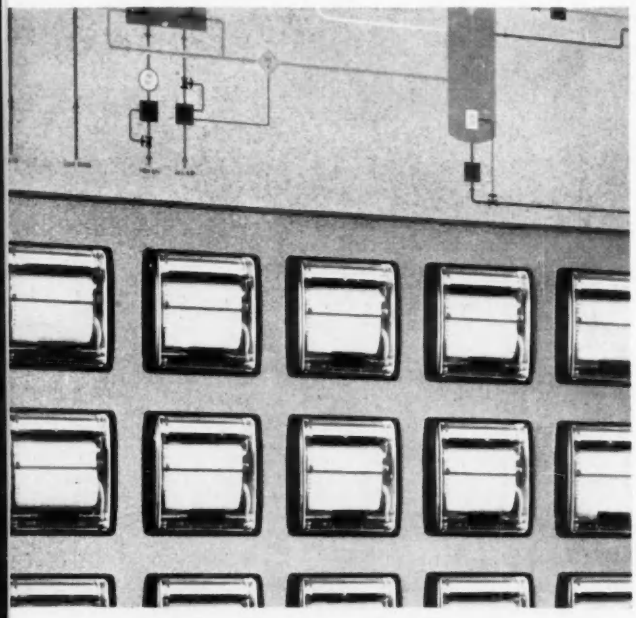


Illustration shows how 4 Consotrol Instruments require less panel space than does a single, conventional 12" recorder.



Typical control panel showing Consotrol Recording Control Stations. Associated M/58 Controllers, integrally mounted, pull out with the recorders.

The ORIGINAL small-case control panel instrument with a FULL SCALE 4 INCH CHART...

Full-scale *readability!* Here is the industry standard set by Consotrol Instruments, with no compromise in compactness, convenience, or performance.

These Recorders and Recording Control Stations are so compact you can actually mount 4 in the space required by 1 standard 12-inch recorder. And yet, inside the case, all components are full size — nothing is "miniature."

With the integrally mounted Model 58 Controller, the Foxboro Consotrol Recording Control Station provides precise, dependable control and full-scale chart records in one-quarter the panel space. Maintenance is easier too, with all calibration adjustments made from the front . . . re-inking needed only twice a year . . . chart changes as seldom as once a month.

For the complete story, write for Bulletin 13-18. **The Foxboro Company, 364 Norfolk Street, Foxboro, Massachusetts, U.S.A.**

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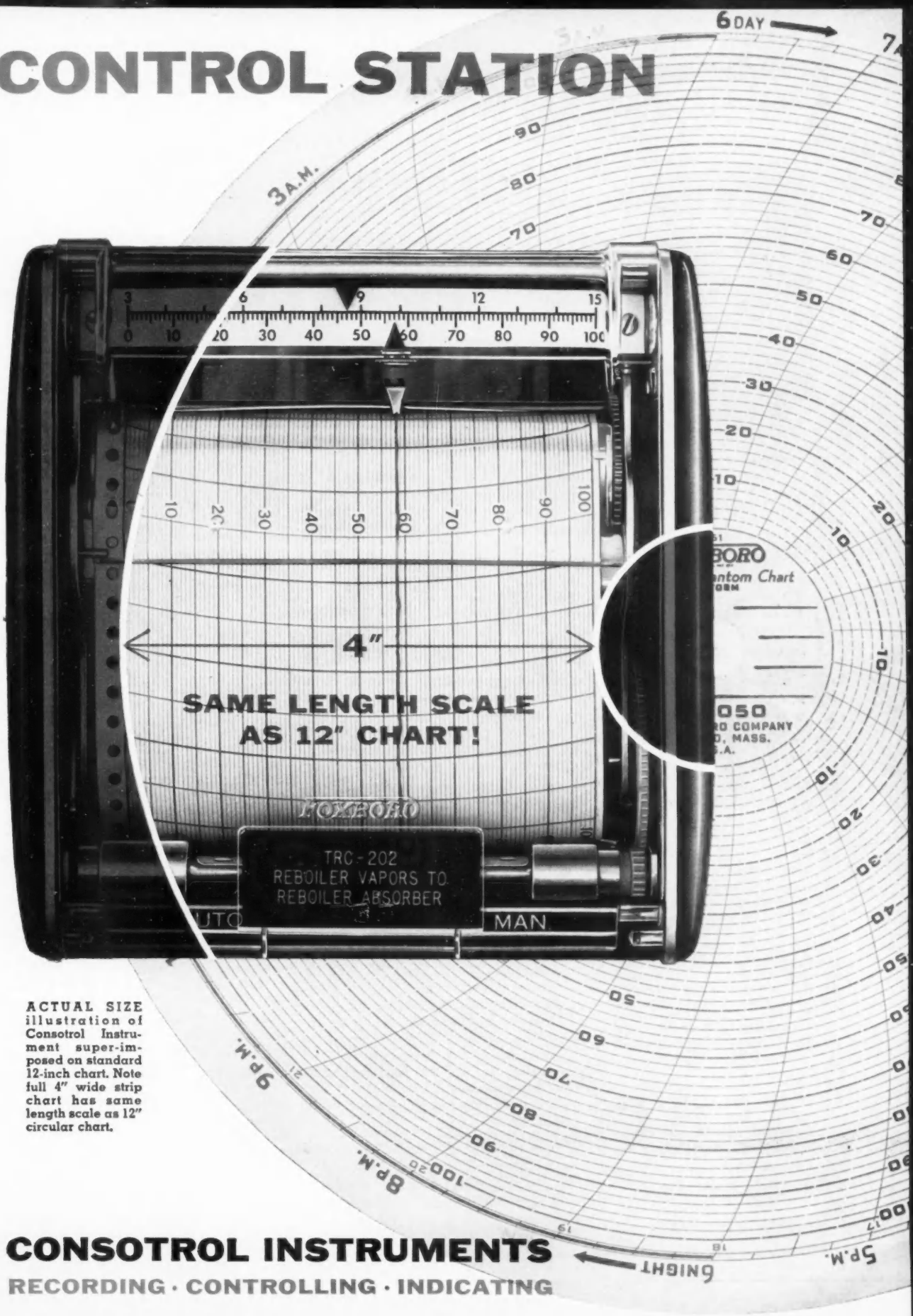
CONTROL STATION



ACTUAL SIZE illustration of Consotrol Instrument super-imposed on standard 12-inch chart. Note full 4" wide strip chart has same length scale as 12" circular chart.

CONSOTROL INSTRUMENTS

RECORDING · CONTROLLING · INDICATING

FEEDBACK

'Tain't right

To the Editor—

In reference to the article published in Data File 11, "Estimating Damping Ratio from Frequency Response", in the Dec. '57 issue of Control Engineering, the equation

$$\phi = \tan^{-1} 2\xi \left[\frac{1}{(4\xi^4 + 1)^{1/2} - 2\xi^2} \right]^{1/2}$$

does not appear to agree with the system described

If the second-order system

$$M = \left[\frac{1}{(1 - B^2)^2 + (2\xi B)^2} \right]^{1/2}$$

and

$$\tan \phi = \frac{2\xi B}{1 - B^2}$$

is the system described, where M is the amplitude ratio and B is the ratio of the input frequency to the undamped natural frequency, the following equation results:

$$\tan \phi \text{ at unity gain} = \frac{2\xi[2 - 4\xi^2]^{1/2}}{4\xi^2 - 1}$$

I believe this is the correct equation to produce the results desired by curve A in Mr. Savant's article. This results in an upper useful limit of the damping ratio greater than $\sqrt{\frac{1}{2}}$, which is in agreement with curve B.

Second-order systems with a damping ratio greater than $\sqrt{\frac{1}{2}}$ will have unity gain only at zero frequency; therefore, curve A could not extend above a damping ratio of $\sqrt{\frac{1}{2}}$.

If I have interpreted Mr. Savant's article improperly please advise me so.

C. F. Sanders
Waco, Tex.

'Tis

To the Editor—

The difficulty which one of your readers experienced in understanding my article in the Dec. '57 issue of Control Engineering lies in the difference between the closed- and open-loop transfer functions. The frequency analysis method (Nyquist plot) is based upon the open-loop transfer function, KG, and not upon the closed loop function $KG/1 + KG$. For the second-order system the transfer function is

$$KG(jB) = \frac{1}{jB(jB + 2\xi)} \qquad (1)$$

where B is the ratio of the input frequency to the undamped natural frequency and ξ is the damping ratio (the same notation as used in the letter). The amplitude and phase response are found from this equation:

$$M = \frac{1}{B[B^2 + 4\xi^2]^{1/2}}$$

and

$$\phi = -90 - \tan^{-1} \frac{B}{2\xi} \qquad (2)$$

The phase margin ϕ_m, which is 180 deg minus the phase lag when the magnitude of KG is unity, is given by

$$\phi_m = \tan^{-1} \frac{2\xi}{B} \qquad (3)$$

from which curve A was derived.

The equation from which you derived the results in your letter is the *closed-loop* transfer function $KG/1 + KG$ for a second-order system. This can be demonstrated by substituting Equation 1 into $KG/1 + KG$ as follows:

$$\frac{KG}{1+KG} = \frac{\dfrac{1}{jB(jB + 2\xi)}}{1 + \dfrac{1}{jB(jB + 2\xi)}} \qquad (4)$$

$$= \frac{1}{jB(jB + 2\xi) + 1}$$

which can be reduced to

$$\frac{KG}{1 + KG} = \frac{1}{[(1 - B^2)^2 + (2\xi B)^2]^{1/2}} \Big/ \frac{2\xi B}{1 - B^2} \qquad (5)$$

It is obviously incorrect to utilize the closed-loop expression of Equation 5 to plot a Nyquist diagram, or to make a Bode plot, or to obtain the phase margin. The theory of servo stability, whether analyzed with the frequency method or with root-locus technique, is based upon the open-loop transfer function KG, and not the closed-loop function, $KG/1 + KG$.

Your conclusions drawn in connection with an upper limit of $\sqrt{\frac{1}{2}}$ for the damping ratio apply only to the closed-loop amplitude response. These conclusions are erroneous, since the phase margin is a measurement based upon the open-loop transfer function. Curve A definitely does extend above a damping ratio of $\sqrt{\frac{1}{2}}$.

I hope this helps you to understand Data File 11. A complete derivation of both these curves will be found in Appendix VIII, *Basic Feedback Control System Design*, C. J. Savant, published this year by McGraw-Hill Book Co., Inc., New York.

C. J. Savant Jr.
American Electronics, Inc.
Los Angeles, Calif.

Put the zeros where they belong

TO THE EDITOR—

In June of last year at your request we filled out a table listing the characteristics of our magnetic modulators. This table was to be used to illustrate an article on magnetic modulators to be published in the November issue of CONTROL ENGINEERING. Upon receipt of our copy of this issue, we read the article and examined the table listing the characteristics. We were astonished and extremely unhappy to find the following errors:

1. The frequency response for all of our modulators was listed as 0.1 sec whereas it should have been 0.01 sec.
2. The weight of our Magnetic Thermocouple Converter MTC435-2 was listed as 15 oz whereas it is only 1.5 oz.
3. Figure 7 lists our modulator as an "odd-harmonic modulator". This is not true. It is a fundamental frequency output type of modulator.

M. G. Tekosky
General Magnetics, Inc.
Bloomfield, N. J.

Our apologies to our readers and to Mr. Tekosky. The article is being reprinted because of a large demand for it. In the reprint the decimal points are in their right places.
Ed.

Another way to avoid oscillations

TO THE EDITOR—

In connection with the article "How to Avoid Extra Integrators When Simulating RLC Networks" by Joseph Otterman in your Nov. '57 issue, your attention is invited to an article by Dr. L. G. Walters entitled "Hidden Regenerative Loops in Electronic Analog Computers", which appeared in the June '53 issue of the "Transactions of the IRE, Professional Group on Electronic Computers". Although Mr. Otterman gives a different rule for avoiding oscillations, I believe both he and your readers may be interested in the earlier article.

Eldridge S. Adams Jr.
Aeronutronics Systems, Inc.
Glendale, Calif.

Or was it O. Henry?

TO THE EDITOR—

We were very pleased to see the interesting report of the Swansea Con-

FEEDBACK

ference of the Society of Instrument Technology, which appeared in the Dec. '57 issue of CONTROL ENGINEERING.

I would, however, like to make one or two comments:

• The name of the co-author of the paper on gas chromatography was D. Harvey, not D. Henry as stated.

• Mr. S. W. J. Wallis, of B.P., was unfortunately prevented from attending the conference, and the remarks attributed to him were made on his behalf by Mr. D. Townend.

Your readers may be interested to note the proceedings of the conference, containing the papers together with the subsequent discussion, will be published by Butterworths Scientific Publications.

T. P. Gray
Secretary, '57 Conference Committee,
Society of Instrument Technology
London, England

Yankee editor apologizes. Ed.

Bids for conveyor systems vary, too

TO THE EDITOR—

Mr. William D. Bell's article, "Why Control System Bids Vary," in the December 1957 issue of CONTROL ENGINEERING, could be retitled "Why Conveyor System Bids Vary" and, with very little change in content, applied just as specifically to the problem as encountered in the materials handling field. Though we rarely find 1,000 percent variations between competitive conveyor system bids, it is not unusual to find variations of 20-30 percent. I'm quite sure that buyers of conveyor systems are as puzzled over this 20-30 percent variation as buyers of control systems are over the 1,000 percent variation Mr. Bell used in illustration.

The six cost factors covered by Mr. Bell should be of value to both buyer and seller of control systems and, as previously mentioned, with very little change apply equally well to the purchase and sale of materials handling equipment. I think Mr. Bell summed up the needed future trend in industrial selling when he wrote, "The manufacturer must understand the client's needs, so that he won't design a Cadillac to do the job of a Ford truck." The emphasis must be, "understand the client's need", not the client's desires. Our experience indicates that once such understanding does exist, particularly when established during the early stages of a job, both buyer and seller can avoid much

NORWOOD CONTROLS

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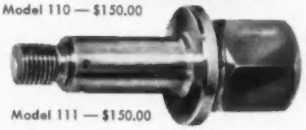

Model 111 — $150.00

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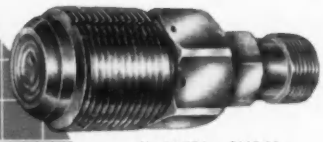
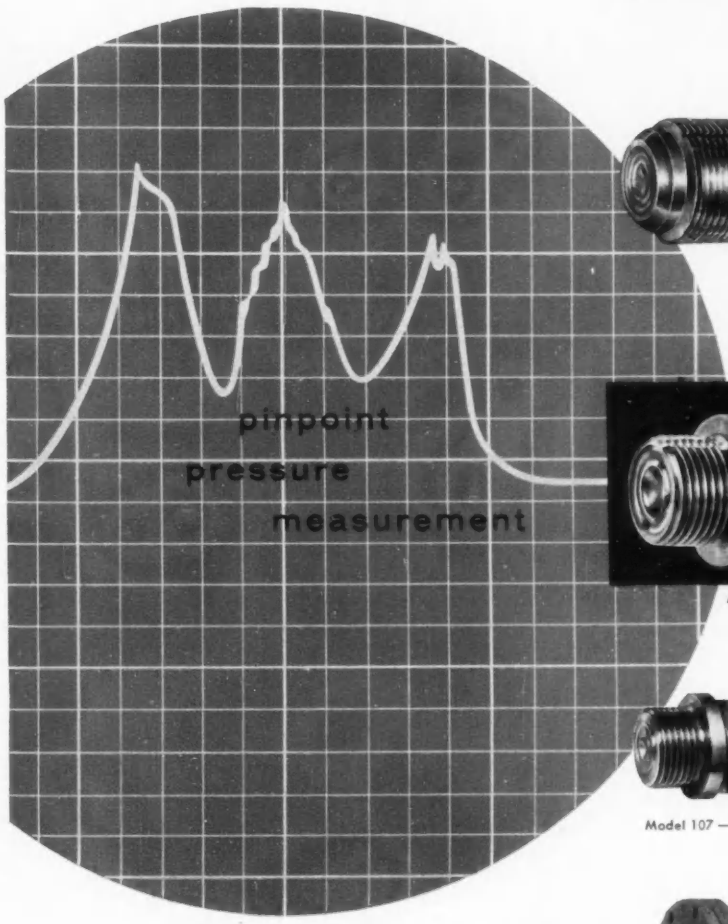


Model 104 — $600.00

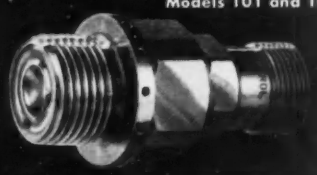
Model 104 Pressure Transducer

For high pressure applications in blast analyses, gun barrel pressures, hydraulic high pressures, etc. Frequency response: flat from 0-20,000 cps.

versatile



Models 101 and 102 Pressure Transducers



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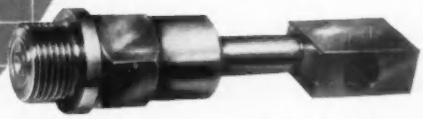
Model 101 — $275.00 Model 102 — $295.00

rugged



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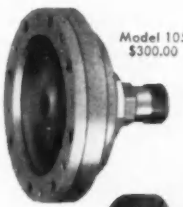
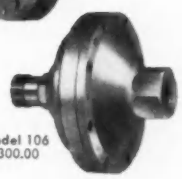
Model 107 Pressure Transducer

Water-cooled, high frequency transducer for pressure studies under very high temperatures. Can be exposed to gas temperatures above 5000°F without damage. All welded construction for any applications, including highly corrosive liquids and propellants.



Model 105 $300.00



Model 106 $300.00

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NORWOOD CONTROLS catenary diaphragm pressure transducers have established new standards of reliability in pressure measurements in dynamic systems . . . gasoline and diesel engines . . . jet engines . . . rocket motors . . . high pressure, high temperature chemical reactions . . . hydraulic and pneumatic systems.

Write for Data Sheets covering Norwood Controls transducers; *which have recently been substantially reduced in price.* **Norwood Controls Unit, Detroit Controls Division, 938 Washington St., Norwood, Mass.**

AMERICAN-Standard PRODUCTS

AMERICAN-Standard

DETROIT CONTROLS DIVISION

FEEDBACK

unnecessary re-engineering, re-estimating, and re-evaluation.

Time will be invaluable to the industrial salesman of the future (and to the industrial buyer, too, we believe). If, through the dissemination of articles of this type, we can save but 5 percent of our sales organization's unproductive selling time . . . we will have made a major gain.

Walter R. Green
Rapids-Standard Co., Inc.
Grand Rapids, Michigan

Wants simplified control math

To the Editor—

In your November 1957 issue, you discussed in your *Abstract* column, under "Simplifying Control Math", the following report:

VDI Forschungs-Heft,
No. 460, 1957.
Dusseldorf, Germany.
Article by I. M. Lorenz

We would like to obtain a translated copy or the original for retention in our library. Could you inform us as to where we might obtain such a copy?

Special Weapons
Canadair, Ltd.
Montreal, Canada

Ditto

To the Editor—

Please refer to the November 1957 edition of Control Engineering magazine. On page 204 of this issue under *Abstracts* is an item titled "Simplifying Control Math". This article is from "Ueber einige Verfahren zur Behandlung von Regelungs-Differentialgleichungen vierter Ordnung und ausgewahlte Anwendungsbeilspiele" by I. M. Lorenz, published in "VDI-Forschungs-Heft", No. 460, 1957, Dusseldorf, Germany.

Engineers in our company are anxious to obtain a copy of "VDI-Forschungs-Heft" or this article and would like a list of articles from the same source containing similar information.

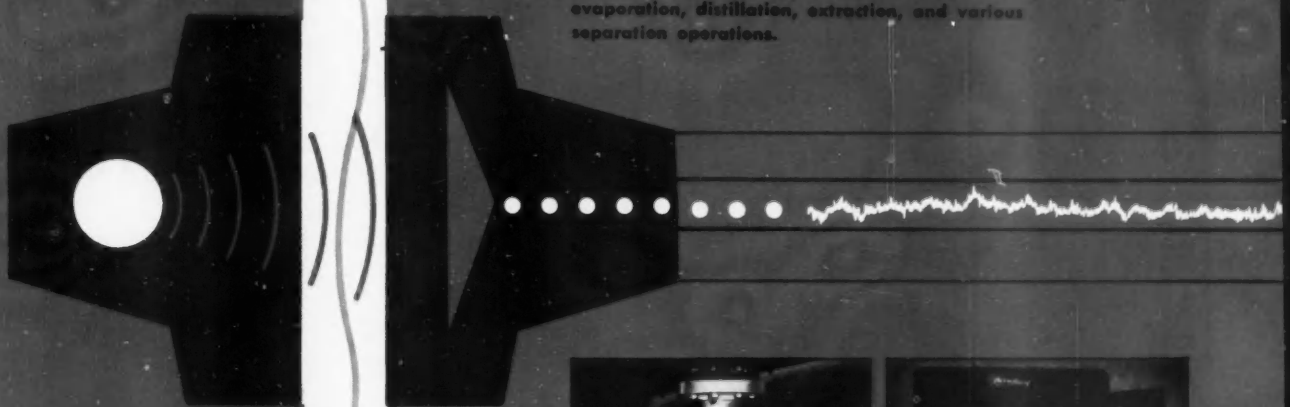
Woodward Governor Co.
Rockford, Ill.

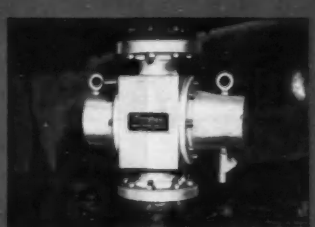
Our Bonn News Bureau says to contact VDI-Verlag Gmbh, Bongardstrasse 3, Dusseldorf, Germany, to obtain copies of "VDI-Forschungs-Heft" or "VDI-Nachrichten", a supplement to it. Publisher is the Association of German Engineers (Verein Deutscher Ingenieure), Dusseldorf. The VDI-Nachrichten appears every two weeks. Foreign annual subscription rate is DM 19.60 plus postage. Ed.

AccuRay® offers continuous flow density systems

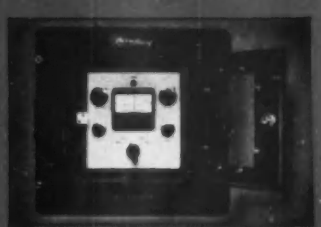
Accurately measuring liquid density, specific gravity, percent solids or related quantity, the AccuRay Density System applies nuclear radiation measurement to process control. Without contacting the process material, measurement is made continuously, independent of flow rate, pressure or viscosity. The AccuRay System is stable and rugged—designed to withstand shock and vibration under the most adverse industrial conditions.

A permanent record of density variations may be obtained by use of an auxiliary electronic recorder. Automatic control may be achieved through use of recorder-controllers and pneumatic or electric final control elements. In chemical, petroleum, food, and mining industries, the density gauge measures feed and yield of various unit operations, including evaporation, distillation, extraction, and various separation operations.





AccuRay Measuring Head Is Easily Installed In Pipe System—Flange Connections.



The AccuRay Density Instrument visually indicates variations in fluid density—may be located remotely from measuring head.

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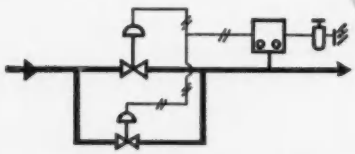
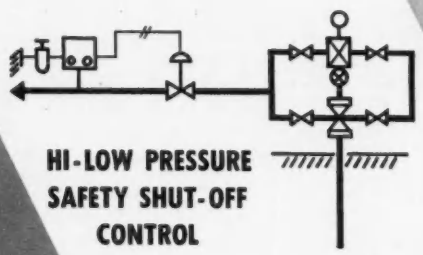
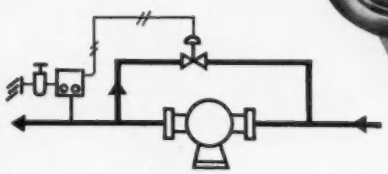


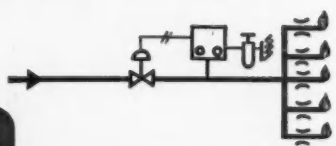
PRESSURE REDUCING CONTROL



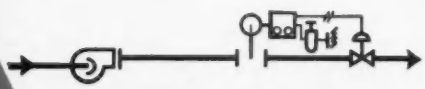
HI-LOW PRESSURE SAFETY SHUT-OFF CONTROL



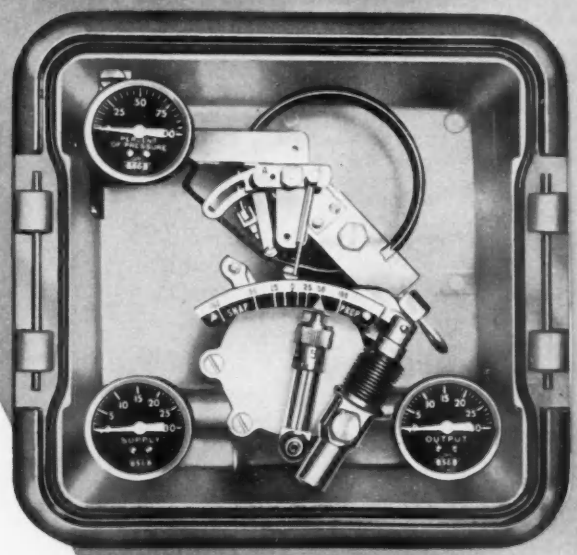
BACK PRESSURE CONTROL



LOW PRESSURE CONTROL



DIFFERENTIAL PRESSURE ...FLOW CONTROL



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George W. Hoover

started with the inside man

Watching a Navy pilot struggle with a problem in a Link Trainer one day in 1938, an instrument instructor suddenly saw that the procedure was all wrong. With his instruments, instructor George Hoover knew exactly what the pilot's position was every minute, but the man inside the trainer had to sweat to find it. "I'm getting the right information," reasoned Hoover, then an aviation machinist 2nd class–naval aviation pilot, "but the man in the trainer is not."

To remedy the situation, Hoover first rigged a plotting board inside the training machine; then he built a device on which the trainee could solve navigation problems. That's when a brand new idea occurred to Hoover. What was really needed, he decided, was a dead reckoning tracker, something to automatically tell the pilot where he is.

Since that time 20 years ago, George Hoover has been pressing his philosophy–"to give the man the right kind of information". In 1942, while assigned to the Navy's Special Devices Section, he designed and built (and patented) the first cockpit instruments which automatically gave a pilot both position and attitude. These pioneering devices combined a mechancial computer (to solve navigation problems) with a polarized film instrument to indicate attitude. Its sensing devices were starkly simple: an air speed indicator, a compass, two gyros, and a manual wind input. The design was successfully flown in 1945.

But the cockpit concept actually lay dormant until 1952. Assigned to the Office of Naval Research, Hoover reopened his efforts to simplify cockpit design, this time working with Douglas Aircraft Co. and Bell Helicopter Co. The first results of this effort matured last fall, when the Hoover concept turned up as a revolutionary cockpit design (CtE, Dec. '57, p. 29), one that uses an electronic digital computer to feed a flat phosphorescent tube.

For Hoover, the simplified cockpit was another step in what is turning out to be a remarkable Naval career. George Hoover joined the Navy in 1934 to fly. He won his wings as an enlisted-man pilot in 1937, and became an instrument instructor shortly after. Because of some fruitful tinkering on the Link trainer, Hoover was assigned to the Special Devices Section from 1942 until 1949. During that period, he was commissioned as a warrant officer, later as an ensign. And at the end of the war, he accepted a permanent commission as an AED (aeronautical engineering duty) officer.

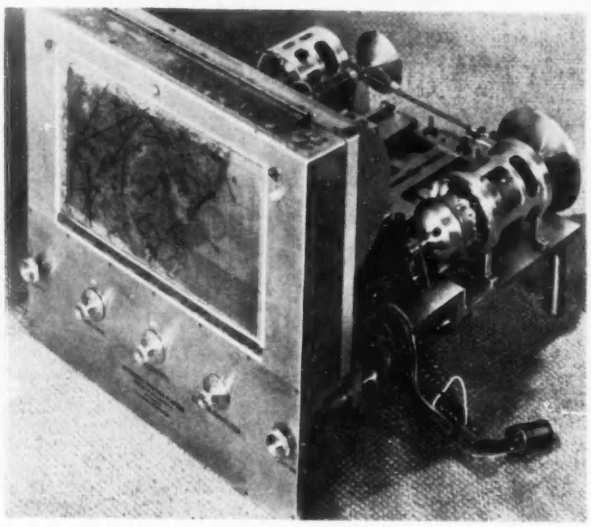
In 1949, the Navy sent Hoover to the University of Nebraska, where his extensive practical knowledge and experience got a chance to catch up with theory. Hoover earned a BS in physics in two years. Then he joined the Patuxent Naval Air Station as instrument officer. And in 1952, he was transferred to the Office of Naval Research to set up an instrument program. Today, 43-year-old Commander Hoover (he looks about 30) is manager, aircraft systems, Air Branch, Office of Naval Research.

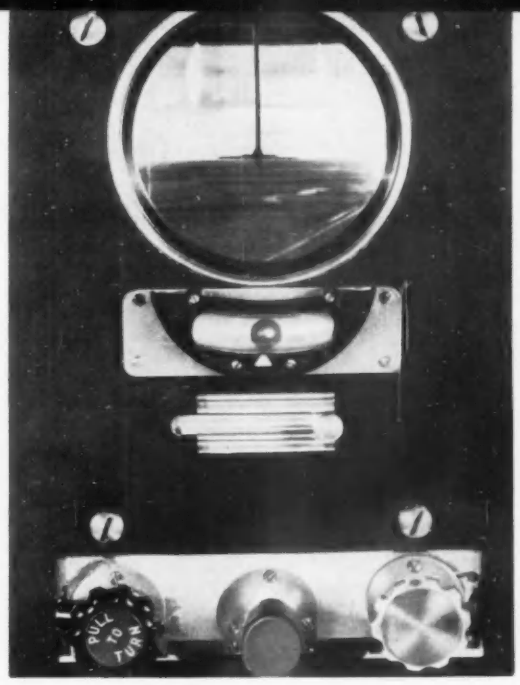
Throughout his work, Hoover has clung to the idea that you can't ignore the man in any control system. During the past five years particularly, he's been a missionary spreading the word about what he feels is the true relationship between man and machines (CtE, Mar., p. 81).

Information, he believes, is the link. Man has to be told what the situation is (in an airplane, where he is) at every instant, and what to do. He says, "Controls are important, but man can't operate them without the right kind of information."

Hoover feels strongly that stressing fundamentals

. . . A CONTROL PERSONALITY





Progenitor of the contact analog was this combination of mechanical computer (left) and polarized film attitude indicator (right) designed and built by Hoover in 1942.

is the way to solve research problems like these man-machine ones. He thinks the U.S. relies too much on experts. Says he, "Things are changing so fast that even an expert can't keep up. Only the fundamental laws of nature don't change."

Following fundamentals has worked for Hoover. He's chalked up a sizable list of achievements. He was responsible for the design of the standard Link Trainer and for the first operational flight trainer; for bringing the Martin Baker ejection seat to the U.S. in 1947, and for the first high-altitude plastic balloon project. His plan: to drop a missile from the balloon to get high-speed and high-altitude data. Some Navy planners thought the project was a joke, but Hoover's balloon launchings were a success. And soon other balloon projects developed to complement his research into cosmic rays, the most recent success being the Air Force's Project Farside (in which a missile was shot from a high-altitude balloon).

Then in 1954, eager for data on man's problems in outer space, Hoover invited a group of distinguished scientists to a meeting in his office. To this group—which included Fred Whipple, Dr. Fred Singer and Werhner Von Braun,—Hoover proposed a project that was to become Project Orbiter, the forerunner of the Army's satellite program.

Inventor Hoover (he holds 6 patents and has 4 more pending) shoots some strong anti-inventor ammunition. He says, "Invention inhibits thinking. When you invent something, invariably you freeze your thinking. Invention should be a rake-off or by-product of a project, not the goal. If it isn't, you get the invention and end up modifying it for the next 20 years to try and make it work."

Instead, Hoover urges creative thinking. "There's only one right answer—the ultimate objective," he says. "On a new project we don't look at the state of the art until we've set all the objectives and requirements."

All this adds up to an unusual twist in weapons system design. As Hoover puts it, "The only weapon for which there is no counterweapon is a better brain. Therefore, what the U.S. ought to be doing is getting more wisdom along with building better weapons." And for this, George Hoover thinks there is no replacement for man.

Tomorrow's aircraft cockpit as George Hoover sees it.

The Lockheed ELECTRA
Takes the Drafts Out of Heating

Most sophisticated automatic temperature control system in a commercial transport runs first aircraft radiant heating system to improve passenger comfort.

The sleek-looking plane shown above on its first air flight is the Lockheed *Electra*, the U.S.'s entry in the competitive turboprop aircraft market. Lockheed feels that the *Electra*'s new radiant heating system—with the most sophisticated automatic temperature controls ever designed for commercial transports—provides a solid improvement in passenger comfort, gives it a healthy edge over other plane makers.

Using an air conditioning system supplied by AiResearch Mfg. Co., Lockheed has abandoned the conventional (and usually drafty) high-velocity forced-air system. Instead, the company is using a low-velocity system. The big complaint raised against low-velocity systems—stratification of air—is handled neatly by radiant heating panels in the cabin walls and floor. These panels also compensate for sensible heat lost by conduction through the walls, windows, and floors of the *Electra*.

Another unusual twist to the system is the fact that the cabin, which uses radiant heating, and the flight deck, which does not, have their own, independent temperature control systems.

The cabin system actually controls three different methods of heating, and two of cooling. Heat is supplied by electric units in the air ducts (for on-ground comfort), by compression (to warm incoming fresh outside air) and by radiant heat (to keep cabin temperatures at the programmed level). Cooling is accomplished by by-passing compressed outside air around an air-cycle cooling turbine, or, for a higher rate of cooling, by turning on a Freon refrigerating unit.

These various air-conditioning techniques are scheduled in response to demand by a series of control circuits mechanically linked together. The cabin programmer (see photo at right) employs a magnetic amplifier driven by a bridge network consisting of the cabin temperature selector, cabin temperature sensor, and a thermally lagged anticipator to damp the system. The output from the amplifier drives the program motor, which positions the cabin program shaft at a rate proportional to the input error caused by the bridge unbalance.

The main program shaft directly controls the Freon selector (for refrigeration) and the radiant panel selector. Following these selectors is a second motor which, with the main program motor, drives the selectors for the duct heaters and the air-cycle system (which brings in fresh outside air) through a differential gear. Its signal comes from a bridge that reports the error between cabin temperatures and duct temperature. This keeps the temperature of air entering the cabin from exceeding the cabin temperature, except for quick warm-ups.

For radiant heating, the cabin is divided into four separate zones: a master zone and three slaves. All the radiant panel temperatures are controlled by separate temperature settings in the individual control circuits. In addition, the slave zones have an added air temperature sensor to bias the output of the main program-driven selector. That means that the air temperature in each zone is main-

tained equal to the air temperature of the master control zone.

The master cabin temperature sensor consists of seven bead- and disc-type thermistors, each calibrated to tolerances so close that they are interchangeable with temperature errors of less than ½ deg F.

Here's how the overall system works. In flight, the pilot sets a desired cabin temperature by turning a rheostat on the instrument panel (he sets a desired temperature for the flight deck by turning a second rheostat, also starts its separate program shaft operating). The programmer then sends heat (or cooling) into the master zone, which is the main cabin, to achieve the desired temperature. As long as there is a difference between the actual temperature in the master zone and the programmed temperature, the bridge circuit is unbalanced, and an error signal goes to the motor amplifier. If the actual temperature is too low, more heat will be supplied by the radiant panels; if the temperature is too high, less heat will be supplied.

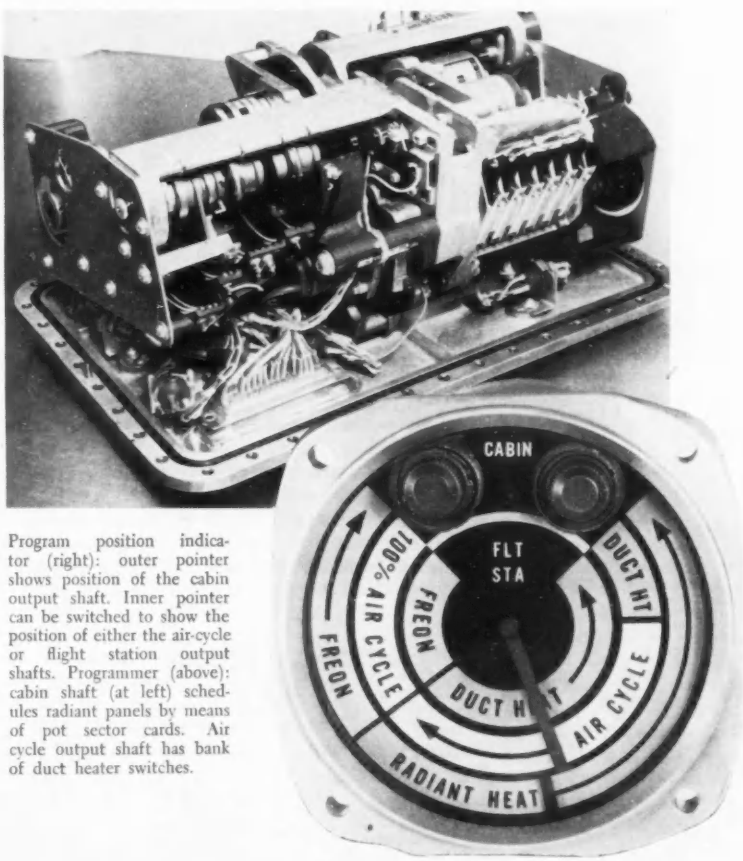
At the same time, incoming fresh air is going through the compressors, which heat it (with the Freon refrigerant turned off). Desired cabin temperature is obtained by by-passing the right proportion of air around the compressor, then mixing the heated and unheated air before its entrance at low pressure and velocity into the cabin.

If by-passing is not sufficient to cool the incoming air to the desired temperature, the Freon refrigeration system is turned on, adding sufficient cool air to reach desired temperature.

The system is so sensitive, says Lockheed, that cabin sensors can detect a group of passengers congregating in any area. The system will then make necessary changes in temperature for the increased activity. The company says that steady-state air temperatures at the sensing elements (both on the flight deck and in the cabin) are maintained within 1 deg F of the selected temperature (deadband less than 2 deg F).

The system has one other feature for quick warm-ups. Special doors have been built into the ceiling to permit the direct entry of hot supply air. The signal for this action is generated by a cabin error, which must be large enough to cause supply air to exceed cabin air by more than 5 deg F.

Scheduled flights of the 400-mph *Electra* will start next fall. First deliveries to airlines (11 have ordered 144) will start in September.



Program position indicator (right): outer pointer shows position of the cabin output shaft. Inner pointer can be switched to show the position of either the air-cycle or flight station output shafts. Programmer (above): cabin shaft (at left) schedules radiant panels by means of pot sector cards. Air cycle output shaft has bank of duct heater switches.

Hughes Puts Digital Control On the Line

LOS ANGELES—

With over 95 percent of its sales stemming from government defense orders, Hughes Aircraft Co. last month moved to reduce its dependency on military work, took careful aim at the burgeoning numerical control field. At a secret plant in Inglewood, Calif., Hughes unveiled a new punched tape control system applied to a line of machine tools that are turning out aircraft parts.

What Hughes has done is apply this punched tape system to three different Kearney & Trecker machine tools—a milling machine, a drilling machine, and a boring machine—and also developed a punched-tape automatic transfer system. Hughes will market the control system, called Digitape, through its Products Div.

Here's how the current line can be used. From a blueprint of the part to be made, a planning engineer lists dimensions and proper sequence of machining operations on a simplified planning sheet. It is then transcribed onto 8-hole punched tape.

Each tape describes the operation for a specific setup on a specific machine. The line can be programmed to perform successive machining operations on a single part or to machine several parts simultaneously. If a part requires milling, drilling and boring, four identical tapes must be prepared (one for each machine tool and one for the transfer system). Once the part is fed into the line, it first moves to the milling machine; then tape controls advance it to the drilling machine; finally it is sent to the last station, the boring machine. In each case, action is delayed until all machines have completed the operation in progress.

If each machine is to work on a different part (no operations in sequence), then the tapes are prepared as if each machine was an entity, not part of a line. That means that the three tools will be directed by entirely different tapes.

Although Hughes is currently using this line to manufacture parts for aircraft control systems, the company points out that Digitape permits wide

(*Continued on p. 23*)

a LOT of Relay in a little space

New Class "E" Relay measures only 2¼" x 1¼" x 1 13/64" minimum (2 springs) to 1 29/32" (10 springs)

This latest Automatic Electric achievement compacts all the features of the famous Class "B" relay in minimum space and weight—with no sacrifice of quality or ruggedness.

LOOK AT THE IMPORTANT FEATURES THIS NEW CLASS "E" OFFERS:

• miniaturized; telephone-style base mounting for rear-connected wiring • heavy-thickness armature arms prevent loss of stroke with large pileups • heavy-duty backstop that won't break or wear out • adequate terminal clearances for easy wiring • long-life, lubricant-retaining bearing arranged to provide a visual check of the heelpiece airline setting without disturbing the adjustment • twin contacts standard; all springs bifurcated for maximum independence • sturdy, strain-relieved heelpiece insures stability of adjustment

Class "E" Relays are available in the following series:

EQA—Quick Acting **ESA**—Slow Acting*
ESO—Slow Operate **EFA**—Alternating Current
ESR—Slow Release **EMS**—Snap Action Contacts
**slow operate and slow release*

Class "E" Relays can be supplied plug-mounted (with or without cover) or hermetically sealed (maximum 4 springs per pileup) in enclosure AE-3300.

• • •

For more information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

99% pure isn't pure enough — the relay iron we use at Automatic Electric must meet specifications of 99.8% purity, including, for example, carbon content limit of .02. To obtain highest magnetic permeability, material is treated for periods up to 7 hours in roller hearth annealing furnaces. Highest standards of quality control insure the well-known dependability of AE Relays and Switches.

AUTOMATIC ELECTRIC

Northlake, Illinois

Subsidiary of **GENERAL TELEPHONE**

flexibility. And the line's products could change tomorrow. Because each unit has its own control system, it is easy to add, replace or rearrange tools in the line.

Each machine tool control cabinet occupies about 50 cu ft. A key component is a binary digital computer with 19 basic circuits. It calculates position and cutting information. To increase reliability under varying power conditions, Digitape uses a motor generator set with solid state electronics for a power supply.

One major advancement claimed is the ease of comparing actual position with instructed position. Here each system relies on a 90-bit register at a 130 kc repetition rate. The output is a signal that drives the servo positioner. Resolution is said to be 0.001 in.; repeatability, 0.0002 in.

Estimated cost of one complete machine is $125,000. About 40 percent of this sum is for control.

Executives at Hughes see Digitape as the company's first serious entry in the field of industrial systems and control. They predict that the combination of numerical control and an automatic transfer mechanism will give job-shop metalworking the advantages of Detroit-type automation.

—Micheal J. Murphy
McGraw-Hill News

UAW Organizing Sputters

DETROIT—

For all intents and purposes the United Auto Workers' ambitious plans to organize engineers have been dumped into mothballs for the rest of 1958. Just about a year ago, the UAW was trumpeting big objectives after winning a representation election for Minneapolis-Honeywell's control engineers. Then UAW set its sights on several independent unions in the aircraft industry and a couple already represented by the Engineers & Scientists of America.

But shortly after the M-H victory, UAW had their win reversed. In a second election, the M-H engineers voted to decertify. The setback slowed UAW plans, made leaders realize that the job of organizing engineers would be no pushover. Some union brass felt that maybe their "pitch" wasn't just right for engineers. At the same time, unions already representing engineers nastily strengthened their hold on members.

Now UAW is getting ready to face up to what could be tough negotiations with the big three auto companies. The union feels that the recession and disappointing auto sales may put steel in the automakers' approach, complicate negotiations. A top union official said, "We just don't have the staff to be active in organizing engineers with current big three auto company negotiations coming up."

On top of that, union brass admit that the Minneapolis-Honeywell upset gave management a psychological victory. As one official put it, "It didn't help. How much it really hurt we still don't know."

ISA Symposium Looks at the Maintenance Problem

Over 400 people from all parts of the U. S. gathered in Wilmington, Del. on Feb. 3 and 4 to kick off ISA's newly formed Chemical & Petroleum Industry Div.'s first meeting. Subject of the symposium-type gathering: "Progress and Trends in Chemical and Petroleum Instrumentation". One trend emerging strong is the growing concern over maintenance problems (see page 73).

Among the outstanding presentations was Jim Combs' (Monsanto Chemical Co.) report on "Process Stream Analyzer Maintenance and Sample System Design". Combs made three main points: first, the importance of the stream analyzer in making a product determines the importance attached to its maintenance; second, the process, the analyzer, and the sampling system must be considered as a complete problem; and lastly, the analyzer house must be large enough to allow personnel to perform maintenance in comfort.

Reviewing the objectives of sampling system design, Combs listed these points: to obtain a representative sample, pretreat it for transmission, transmit it to the analyzer, condition the sample for admittance to the analyzer, control sample pressure and flow, distribute sample and reference gases, and make sure the sample is appropriately vented.

This paper triggered a flood of questions from the audience. Typical queries: What type of filter to use in the sampling system? Combs' answer: 10 micron cartridge-type for solids and liquids. Do you ground electric analyzers? (Yes, to eliminate 60 cps pickup.) Where do you get accurate reference samples? (Monsanto makes its own, then waits 72 hours to assure components do not stratify.) Do you have to design your own sampling systems? (Yes, for the present; but Monsanto plans to rely more on manufacturers of stream analyzers for sampling systems.)

One of the most vocal sessions was a panel on contract maintenance. Presenting contractor viewpoints were Neil Blair and Web Willis, both of Panellit Service Co. Ed Roth, instrumentation coordinator at Tidewater's Delaware City refinery, took the user's view. Most of the discussion centered around how Panellit's maintenance contract, in force now for over a year at Delaware City, has been working out. No dollars and cents figures are yet available for publication, but both sides felt that it has worked out pretty well. However, they also indicated that a lot of improvement is still necessary to reach the level of plant efficiency needed by the client and the level of profit wanted by the contractor.

IBM's Vice-President Cuthbert Hurd, speaking at the banquet, warned of present perils in the science fields, particularly instrumentation. As he sees it, the U. S., with less than half as much qualified personnel, must double its present efforts if it is to retain military and economic advantages over Russia.—Harry R. Karp

Controlled rectifier . . .

. . . made its public debut at the IRE show. The silicon device, which promises to replace the thyratron in many applications, was developed by GE's Semiconductor Products Dept. This sample can handle loads varying from 200 to 1,000 watts at a stud temperature of 125 deg C. When switching at full rating, the controlled rectifier dissipates only one-half of 1 percent of the controlled power (CtE, March 1958, p. 132)

The Submarine that Flies

Up to now, the sea-going Navy has shied away from systems-engineering its ships. Instead, the Navy has preferred to develop each major portion of the ship separately: the power plant, fire-control equipment, communications gear, and navigation equipment. But now, in a small, crowded, second-floor room at the Office of Naval Research, the fleet's first systems engineering project is taking shape. It's a submarine that "flies" through the water.

Named Project Subic—In Project Subic, the Navy is applying the systems approach to a complete submarine design. But Subic is more than just a first effort at systems engineering; it could revolutionize the U. S.'s defense plans by providing the country with mobile underwater missile launchers that are difficult—if not impossible—to defend against.

As a starting point, the Navy has adopted the premise that a submarine is closely related to a space ship; the major difference is the medium in which the vessel operates. Space ships and submarines have these features in common:

- Both must supply a satisfactory environment for their crews for long periods of time.
- Both must perform their own logistical support for long periods of time.
- The problems of control are identical. The biggest one is information: how does a crew know its position at all times?
- Both need a true inertial space sensor to supply space information.
- Escape and survival problems are almost equally difficult.

It started with atoms—It took the Navy's atomic-powered submarine *Nautilus* to start the kernel of the Subic project growing in the Navy. The *Nautilus* gave the fleet its first true submarine: with its atomic-powered plant, the *Nautilus* cruises better underwater than on the surface. In addition, ONR has a flock of recent Navy-inspired scientific developments to draw on for project Subic. Many of these emphasize the similarity of the sub to a space ship. For example:

- The sleek underwater design of the Albacore-type hull, which makes submariners talk of "flying subs" through the water. The Albacore hull is the first designed particularly for high speeds underwater.
- A ship inertial navigation system (SINS) that flies the submarines underwater.
- The contact analog (CtE, Dec. 1957, p. 29) which will give a submarine commander detailed information about his position and attitude on a television-like screen. (Said a submariner to Navy air man Comdr. George Hoover, who sparkplugged the development of the contact analog, "This thing is even better for subs than it is for planes.")
- The Polaris, a dry-propellant missile which will give the submarine a 1,500-mile-range weapon.
- A seaborne digital computer developed for the ASROC (Anti-Submarine Rocket) program.

Although cautious scientists at ONR say it will be three to five years before any of the Subic-class subs join the fleet, it's possible to put together now a picture of what this superweapon will look like. It will have a hull with underwater streamlining similar to that of the Albacore; its nuclear reactor power plant will be designed with a missile launching mission in view; navigation will be performed by a specially designed seagoing inertial guidance subsystem; and the size of a submarine will permit the use of a central digital computer to solve both navigation and fire-control problems.

• **Six-in-one controls**—Probably the biggest change from present technology will take place in the control system. Command of the sub will be exercised through control of six basic loops: ship control, engineering control, communications, casualty control, environmental control, and weapons or fire control. In the Subic, these control loops will be integrated into a single system whose overall control is exercised by one man. (At present each is a separate system. Recently it's been possible to combine steering and diving into a single loop, controlled by one man.

It's still too early to say when the first Subic-type sub will be launched. But the place will be Groton, Conn. System manager for the project is Electric Boat Div. of General Dynamics. And working closely with ONR is the Navy's Bureau of Ships.

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HIGH STABILITY
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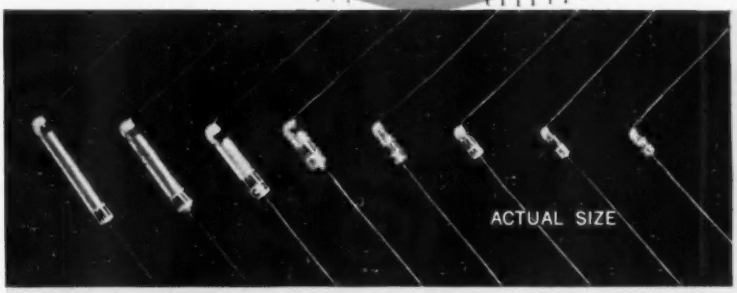
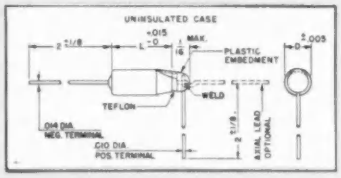


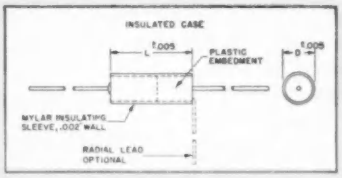
SERIES TW WIRE-TYPE TANTALUM CAPACITORS

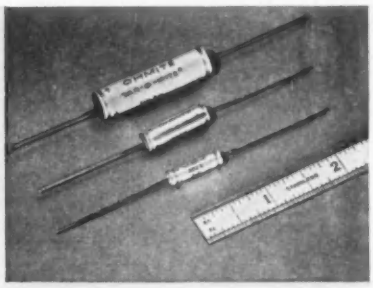
These new subminiature, wire-type units feature greater capacitance per unit volume, lower leakage current and power factor, and small capacitance drop at extremely low temperatures as compared to other types of electrolytics. Ultrasmall for low-voltage DC transistorized electronic equipment, these new tantalum capacitors have *high stability, high capacitance, long shelf life, and excellent performance* under temperature extremes of—55°C to + 85°C. Available in eight subminiature sizes; 0.1 to 80 mfd. over-all capacitance range.

SIZE	UNINSULATED		INSULATED	
	D (inches)	L (inches)	D	L
*T	.075 (5/64)	.156 (5/32)	.082	.203
*S	.075 (5/64)	.187 (3/16)	.082	.234
*M	.095 (3/32)	.172 (11/64)	.100	.218
*A	.095 (3/32)	.250 (1/4)	.100	.312
*B	.125 (1/8)	.312 (5/16)	.134	.375
C	.125 (1/8)	.500 (1/2)	.134	.562
D	.125 (1/8)	.625 (5/8)	.134	.687
E	.125 (1/8)	.750 (3/4)	.134	.812

Smallest size is .075 (5/64) x .156 (5/32) inches; the largest is .125 (1/8) x .750 (3/4) inches. Five stock sizes (*) are available in a wide range of capacitances and voltages. Units insulated with a tough Mylar® plastic sleeve can be furnished. *Write on company letterhead for Bulletin 148B.*







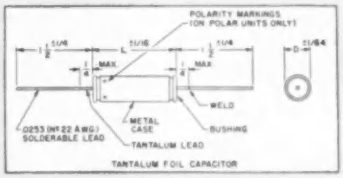
SERIES TF FOIL-TYPE

These capacitors are tantalum foil, electrolytic units designed for low voltage AC and DC applications where small size, top performance, and stability of electrical characteristics are required. Units feature unusually long shelf and operating life.

CASE SIZE	D*	L*
J	3/16"	1 1/16"
K	9/32"	7/8"
L	3/8"	1 7/16"

**Add 1/16" to L and 1/64" to D when insulating sleeve is used.*

Three sizes now available; .25 to 140 mfd. over-all capacitance range. Standard tolerance is ±20%. Working voltage up to 150 volts. Polar and nonpolar units are available. *Bulletin 152.* Design and construction meet military specification MIL-C-3965, paragraph 3.3.



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WHAT'S NEW

Conclaves Ahead

Here are some April meetings that accent the growth of sophisticated control among machinery designers and users. At the Design Conference, the spotlight is on servo systems at work.

ASME DESIGN ENGINEERING CONFERENCE, APRIL 14-17

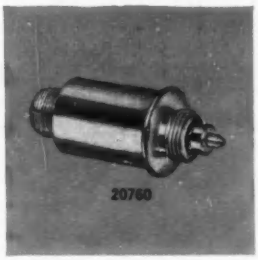
This year's ASME Design Conference, scheduled for Chicago's Amphitheatre, indicates a new interest in sophisticated control by the designers of machinery. For example, both papers in the first mechanical session of the conference—Tuesday, April 15—impinge on the control field. One is "Mechanical Memory Devices" by A. Mirel, American Machine & Foundry Co.; the other: "Automatic Inspection Devices" by D. H. McConnell, Sheffield Corp.

The two control sessions are devoted almost entirely to presentations of servo systems at work. In the Tuesday session, the technical papers to be presented are: "Electrohydraulic Systems on Machine Tools" by E. J. Rivoira, Cincinnati Milling Machine Co., and "Electrohydraulic Control Systems for Aircraft Applications" by F. L. Moncher and L. D. Taylor, Vickers, Inc.

In Wednesday's control session, both papers tackle problems in designing servo systems. The first, entitled "Integrating Mechanical and Electrical Design in Servo Systems", is by W. L. McCann, Giddings & Lewis Machine Tool Co. The other paper is "Solving Mechanical-Electrical Problems on Servo Systems" by G. Ertell, General Electric Co.

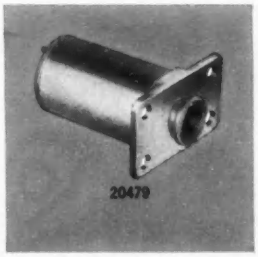
In the General Engineering session, one of the papers appears to have special interest to control engineers. That's the presentation, "Information Center of Tomorrow", in which A. Kent and J. W. Perry of Western Reserve University describe present and proposed methods for analyzing, storing, selecting, and retrieving engineering and scientific information.

Along with the conference will be the 1958 Design Show, featuring exhibits by more than 400 manufacturers. Advanced registrants will receive a plastic inquiry plate (much



true hermetically sealed solenoids

Just like a sealed vacuum tube! True hermetic sealing around a solenoid... glass seal terminals, lugs, and connectors. All welded and brazed construction. Completely plated after assembly. Exceed most requirements of military specification MIL-S-4040 (USAF). Priced at approximately the same level as conventional types.



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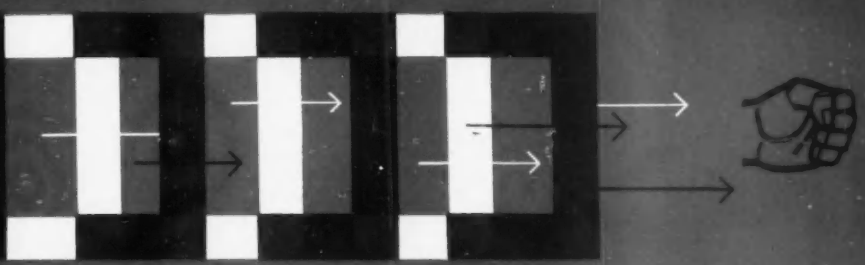
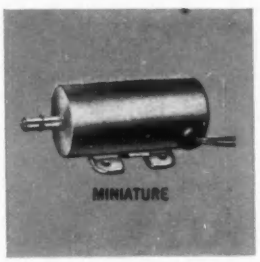
D.C. solenoids





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Having trouble finding solenoid specialties? Here at Cannon, we'd like to help you. Standard production now includes multiple-strip solenoids for keyboard operation, locking types requiring no holding current, and miniatures and sub-miniatures ½" diameter. In addition, our expanded solenoid engineering department is ready to serve you at any time.

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Factories in Los Angeles, Salem, Mass., Toronto, London, Melbourne. Manufacturing licensees in Paris and Tokyo. Representatives and distributors in all principal cities. See your Telephone Yellow Book.

Please ask for latest SR-S releases and/or Solenoid Bulletin.

WHAT'S NEW

like a charge plate at a department store) with their name and address embossed on it. The plate is expected to reduce filling out literature requests and is being used here for possibly the first time.

AUTOMATIC CONTROL TECHNIQUES, APRIL 14-16

The first joint conference on automatic control techniques is scheduled for Detroit's Hotel Statler, April 14 to 16. A joint venture of AIEE, ASME, and IRE, the meeting will bring together members of different societies interested in the use of electrical, electronic, mechanical, hydraulic, and pneumatic media to solve automatic-control and data-handling problems for industrial production.

Papers cover a variety of industries. For instance, for utility control engineers, A. C. Hartranft and F. H. Light Jr., Philadelphia Electric Co., will present a "Survey of the Application of Automatic Control Devices for Electric Power Generation". At least two articles will discuss steel mill control. And three others will tackle various phases of numerical control for machine tools.

Other speakers will discuss application of computers and automatic data processing in fields that range from highway design to manufacturing production control.

Co-chairmen of the meeting are G. W. Heumann (General Electric Co.), who is head of the AIEE Joint Div. Committee on Automation & Data Processing, and T. H. Belcher, Michigan Bell Telephone Co.

California Union Okays Fifth-Year Training In Electronic Controls

SAN FRANCISCO—

In California, a move to add a fifth year to an electrician's apprenticeship—a year devoted to electronics—received the blessings of the state organization of the International Brotherhood of Electrical Workers.

The state labor group—called the California State Association of Electrical Workers—gave as its reason for recommending the fifth year the increasing use of automatic controls in industry. This, it said, makes it necessary for an electrician (or inside wireman, as he's known in the construction industry) to know how to install electronic controls.

IBEW spokesmen in the San

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WHAT'S NEW

Francisco Bay area pinpointed the problem: "Our electronics work has increased 20 percent in the past three years." And industry sources foresee more electronics work in commercial and residential installations, as well as industrial jobs.

California apprenticeship officials seem to agree that electronics training is needed; but there's a difference of opinion on the fifth year of training. Some suggest tossing out certain portions of the present training program and substituting electronics, thereby squeezing the whole program into four years.

Another proposal is to make the fifth year optional. A man would then become a journeyman inside wireman in four years, an inside wireman and electronic technician in five years.

Details of the fifth-year program are still to be worked out. Next step: decision by the joint statewide electrical construction industry apprenticeship committee on new apprenticeship standards.

Local joint apprenticeship committees are not bound by the state group's decisions, but they usually go along. It would be up to local collective bargaining to decide whether an inside wireman would have to serve a five-year apprenticeship. If the five-year program is adopted by the state committee it may be incorporated in some labor contracts due for renewal this June.

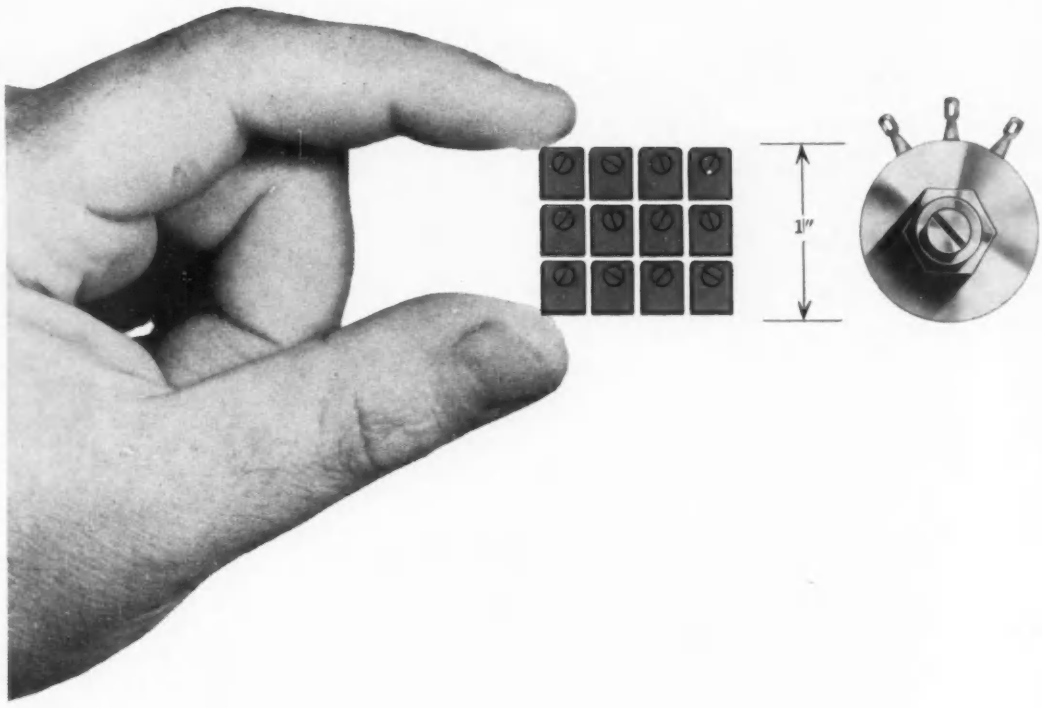
The program would be for men who do electrical installation and maintenance work. It would not include workers in electronic manufacturing plants or television.

—Sue Johnson
McGraw-Hill News

Automatic Parking Garage To Coddle Cars

World's first completely automatic parking garage will be built in New York City by Speed-Park, Inc., for Columbia University. Based on a design by Mihai Alimanestiano, the garage will noiselessly park or discharge as many as three automobiles per minute.

Automatic operation is all actuated by a key. When a motorist arrives at the garage, the cashier will remove a numbered key from a central control panel. That starts a individual meter recording the time and corresponding charge for parking. Removal of the



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You can pack 12 Bourns TRIMPOT® potentiometers in the 1-square-inch area occupied by the average single-turn rotary.

Fit the TRIMPOT into corners—between components—flat against a chassis or printed circuit board. Mount them individually or in stacked assemblies. Any way you use them—Bourns potentiometers save space!

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key also opens an elevator door and sees to it that the car is picked up under the tires by a conveyer and moved laterally into the elevator. Then the door closes and the elevator moves to the proper floor, where the car is transported to a locker whose number is on the key given to the motorist.

When the motorist returns the key and it is reinserted in the control panel, the process is reversed. Speed-Park estimates an average time of 57 sec to return a car.

Also associated in the venture is the Otis Elevator Co., which will manufacture, install, and maintain the control hardware.

Committees Plan Pipeline Control Standards

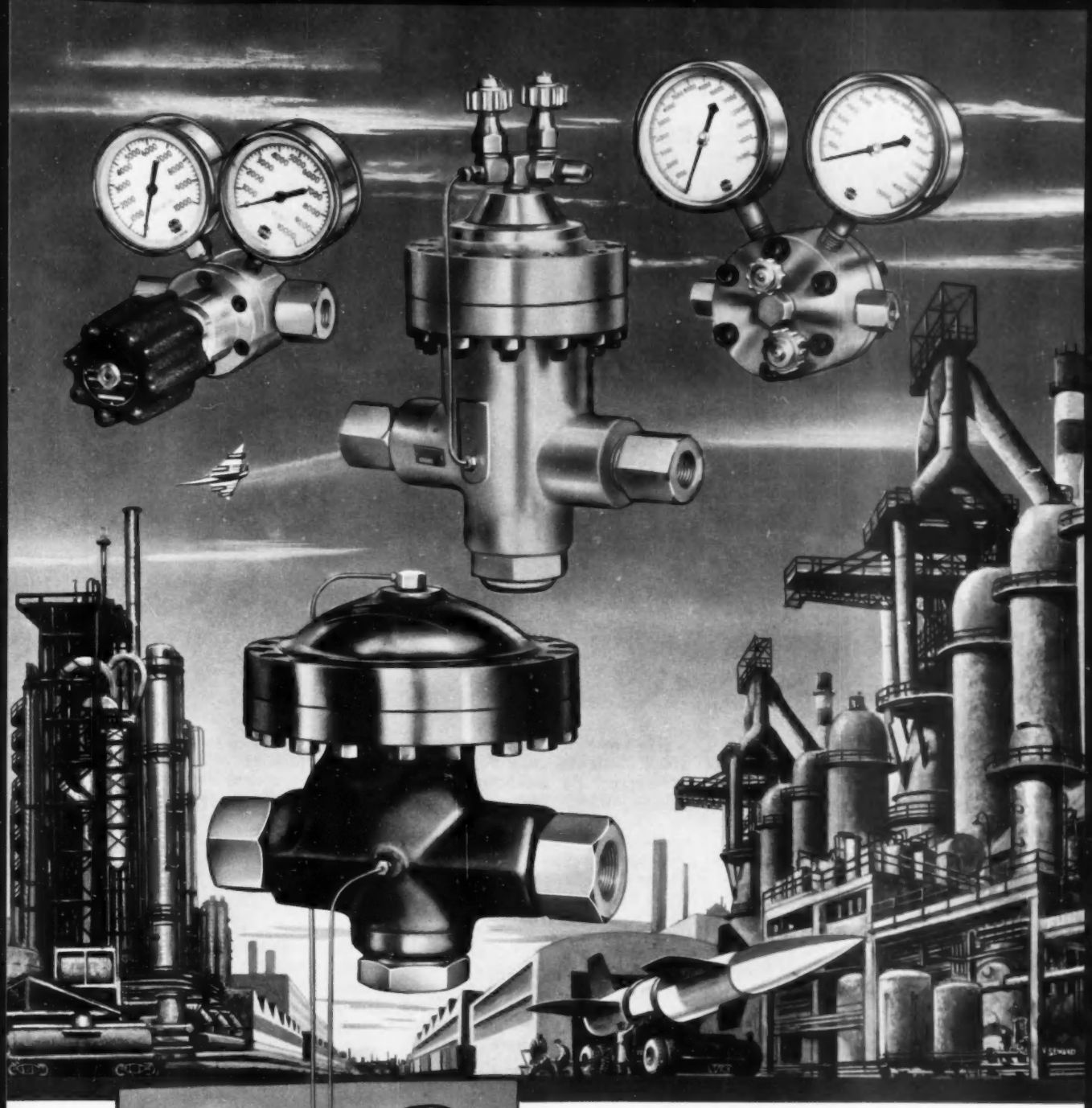
Two committees of engineers interested in applying automatic controls to pipelines met recently in Tulsa to coordinate activities in advancing the technology of liquid pipelines. The groups: the Liquid Pipeline Committee of ISA and the Automation Committee of the American Petroleum Institute.

The big reason for the meeting was to coordinate schedules of projects for 1958. The API committee drew up this program for the coming year:

1. Supplement bibliography on automation of pipelines.
2. Conduct an industry survey on pipeline automation.
3. Observe industry trends in automation and report significant developments.
4. Prepare Pipeline Industry Standards for communications.
5. Promote cooperative efforts with established technical groups.

The ISA Committee presented a six-point program for 1958:

1. Establish requirements for electric control valve operators for pipeline service.
2. Obtain factual presentations of dynamic or closed-system pipelines.
3. Conduct a pipeline symposium at the September 1958 ISA National Meeting.
4. Issue Pipeline Industry Standards maintenance bulletins and instruction manuals.
5. Determine requirements for data-handling equipment for pipeline applications.
6. Keep management informed about terminology, business techniques, and research operations.



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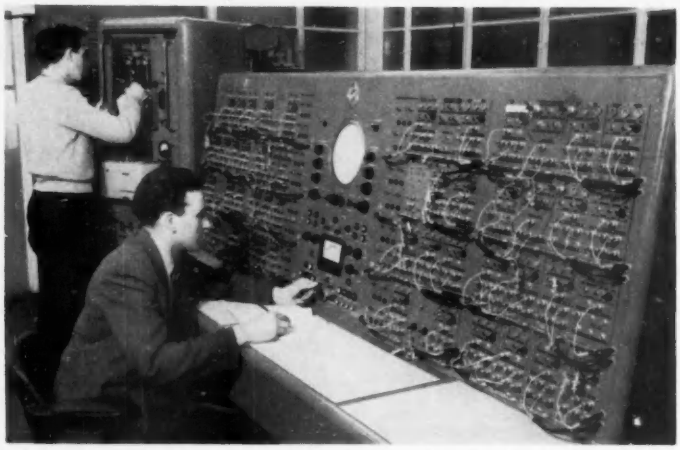
EUROPEAN REPORT

Simulation Answers a Process Stability Question



The final stage in the simulation—Emiac I analogs the closed loop

Simulation of chemical processes is still in its infancy in Britain. But in February, the technology took a giant step forward when a joint EMI-Laporte Industries team completed the simulation of a plant scheduled to go onstream in May. This was the first time in Britain that a whole process of this complexity has been successfully simulated, including settings, pipe lags, pumping and other characteristics.

From this success came two results: first, chemical manufacturer Laporte obtained full start-up and shut-down procedures for its plant, controller settings throughout the plant, and overall phase and stability margins—before the plant was completed. Second, EMI Electronics, Ltd. put itself firmly into the process simulation field.

• **Verifying an approach**—The completion of this project verifies the view (prevalent in Britain) that a mathematical approach can solve simulation problems without extensive plant data.

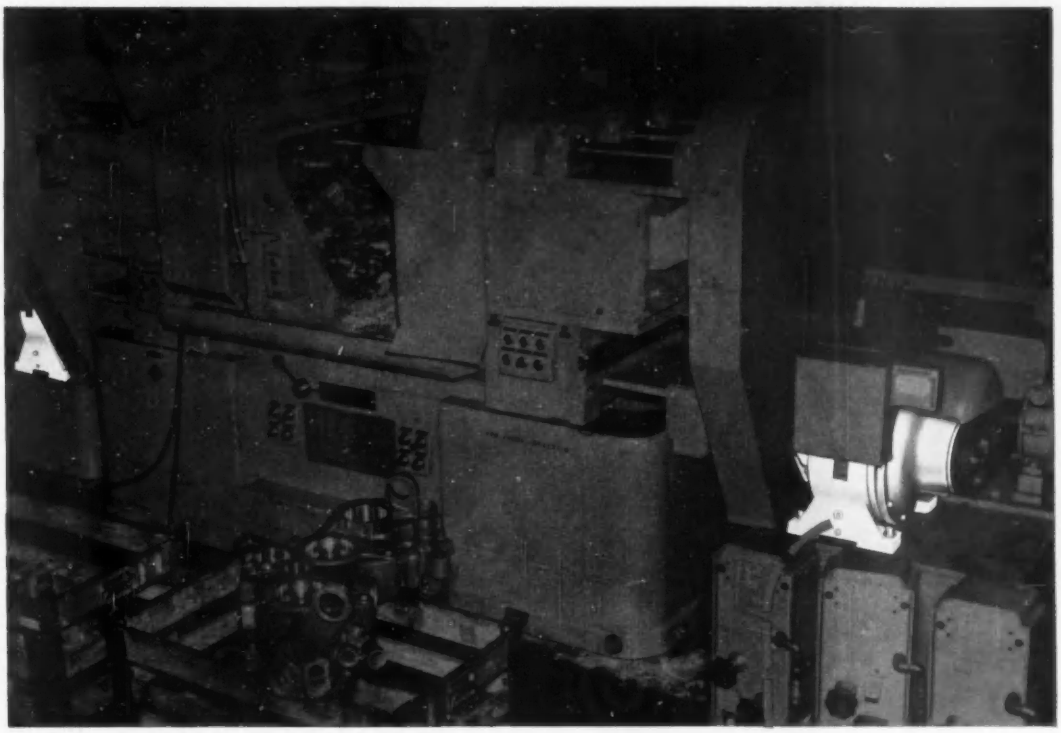
In this study, the process was a new development; it involved surge tanks, reaction vessels, and a 24-plate extraction column in a closed system with seven subsidiary loops.

One reason for starting simulation was that Laporte's pilot plant for the new process showed traces of instability. The chemical company felt that analysis was essential before proceeding to full-scale plant design. And because of the nonlinearities of the system, some kind of computing aid was required.

That's when the chemical company teamed up with the electronics manufacturer. Laporte undertook the detailed analysis of the physics involved in certain complex portions of the plant; EMI's mathematical team, headed by A. H. Doveton, then rearranged these to provide the transfer junction for each portion. Then EMI—anxious for confirmation of the validity of the mathematical model—synthesized Laporte's pilot plant to obtain behavior correlation.

• **EMIAC at work**—To do this job, EMI used the EMIAC I computer, a development of GATAC, Europe's largest commercial analog computer, with the successful solution of Britain's Seaslug missile dynamic problems to its credit.

One of the features of GATAC and its derivatives EMIAC I and II is the ease with which their variable mark-space multiplier systems provide conversion between frames of reference in relative motions. These systems eliminate the normal electromechanical servos by using time division. One



Machining speeds tailored to wide variety of metals with Cleveland Speed Variator

In the manufacture of aircraft engine components, Cleveland Speed Variators permit fast, accurate adjustment of machining speeds to the exact rpm required for various metals from magnesium to 38 Rc steel.

Infinitely variable, the Speed Variator provides continuous speed progressions over its full 9:1 range . . . from ⅓ to 3 times input speed. Manual or automatic remote control instantly and smoothly adjusts output speed. Variator is rugged, compact, quiet running.

For full details—photographs, sectional drawings, rating tables, specifications—write today for Bulletin K-200. The Cleveland Worm & Gear Company, Speed Variator Division, 3260 East 80th St., Cleveland 4, Ohio.

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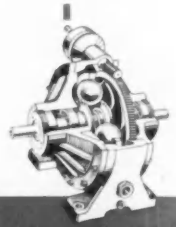


HOW IT WORKS

Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, right).

CLEVELAND SPEED VARIATOR

WHAT'S NEW

. . . studying the scale-up, they found that the non-linearities were not so serious . . .

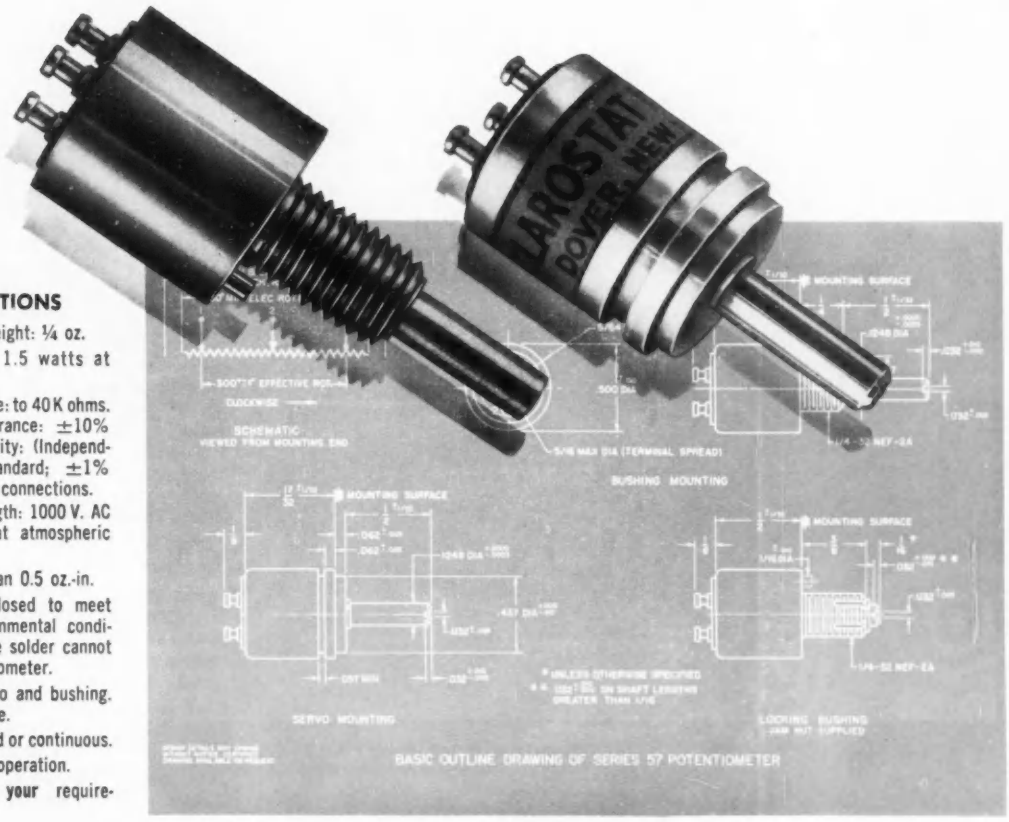
variable controls the amplitude of a train of rectangular pulses and the other proportions the mark-space ratio, and the mean amplitude gives the product of the two inputs, which can be integrated as required. Using this system, EMI was able to generate those nonlinear functions that were products of time variables; diode function generators provided the remaining functions.

The first results of the mathematical analysis did not show up the pilot plant instability. Digging deeper, EMI and Laporte found that certain inherent lags were more critical than realized; introducing these gave results that cross-checked with reality and set the stage for the scale-up to full plant.

In studying the scale-up, Doveton's team found the nonlinearities of the pilot plant were not so serious and a linear relationship could be used. For both the pilot and main plant, hand integrations were necessary to convert the partial differential equations of the reaction columns to a form involving time as the only independent variable. This allowed a simple four-terminal network to be realized for each portion of the plant.

• **Using computer hardware**—All 16 equations representing the dynamic mass balance of the closed-loop process were simulated on only 30 amplifiers, 11 integrators, eight function generators and five multipliers. The equation took into account the transport lag and damping effect occurring at each of the 24 extractor column plates, the gas compressibility in the absorber column, and the physical limits on controller responses and valve positions. Simulated also were dead times and lags of the pneumatic signals from the five level controllers.

Turning hours into minutes by means of 60:1 time compression factor on the computer, Laporte quickly found that simple proportional control on the seven subsidiary loops achieved the required stability, and that the pumping capacities were adequate. Step injections of flow and pressure variations allowed the rate of disturbance propagation through the system to be observed. These highlighted the variation in gain in the forward and backward paths and



SPECIFICATIONS

- Size: ½" dia. Weight: ¼ oz.
- Power rating: 1.5 watts at 40° C.
- Resistance Range: to 40K ohms. Resistance Tolerance: ±10% standard. Linearity: (Independent) ±2% standard; ±1% special. Welded connections.
- Dielectric Strength: 1000 V. AC for 1 minute at atmospheric pressure.
- Torque: Less than 0.5 oz.-in.
- Completely enclosed to meet toughest environmental conditions. Applicable solder cannot get into potentiometer.
- Mountings: Servo and bushing. Also locking type.
- Rotation: Limited or continuous.
- High-frequency operation.
- Modifiable to **your** requirements.

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Designed to meet the ever-increasing demand for greater performance and highest reliability in less space, the Clarostat Series 57 Precision Potentiometers feature a new rotor and brush assembly for maximum stability and longest trouble-free service. Nickel-silver body. Thermally compatible cover with sturdy terminals molded in place. ■ Write for details . . .

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WHAT'S NEW

the nonlinearities of the system resulting from positive and negative displacements as well as from amplitude sensitivity.

Laporte's control engineer K. C. W. Pedder reports that the simulation cost his company $7,000. Says he, "For our $7,000 investment, we have got more than just stability criteria. The experiences of the future plant's behavior gained in the two-month computer study has given us foreknowledge which will probably save us a number of expensive shutdowns."

—Derek Barlow

Intrinsic Safety:

Will It Spread?

Because of the influx of electronics in the process industries, the question of safety standards in hazardous locations is demanding a lot of attention. In the United Kingdom last month, work proceeded on a draft safety code for consideration by the International Electro-Technical Commission. But some international complications loom on the horizon, for European practice differs greatly from that followed in North America.

Two factors characterize Britain's approach. First, intrinsic safety is pioneered as an alternative to explosion-proofing; second, all testing, certification and inspection has the force of law and is operated by government departments.

In other countries, intrinsic safety is often recognized, but less highly developed; flameproofing certification is carried out frequently by private associations. British practice recognizes only a hazardous or nonhazardous area, and there is no equivalent to the American Class 1, Div. 2: British flameproofing practice corresponds roughly to North American explosion-proofing.

In Britain, testing is carried out by the Ministry of Fuel & Power; approval and inspection is operated by the Factories' Branch of the Ministry of Labor. Intrinsic safety certification is operated by the same authorities, and government-sponsored research work on this has been continuous since World War I.

Intrinsic safety is the key. The basic principle: if the energy in an electric circuit is below a critical level, any sparking resulting from its use will be innocuous. Hence, the expense and weight of a special enclosure does not arise. There is a universal precedent for such a philoso-

phy—everyone agrees that a thermocouple for temperature measurement does not require an explosion-proof housing.

Advocates of intrinsic safety claim it is superior to the explosion-proof enclosure because safety does not depend on the correct replacement of covers or the isolation of the supply before servicing. Also, it is applicable to severe hazards, such as hydrogen, for which explosion-proofing is difficult to achieve. It is limited, however, to light current circuitry—but signaling, controls, and some portable test equipment fall within this scope. As an alternative, the circuit can be split into safe and unsafe portions, with the power source contained in a suitable enclosure or mounted outside the danger area.

But there is still at least one stumbling block. In spite of a wealth of accumulated information, the safety of any particular circuit cannot be fully predicted, and each equipment has to be individually tested before certification. The critical energy level varies for different hazards, and is greatly influenced by the inductance of the circuit. The British Electrical & Allied Industries Research Association has been correlating these facts for four particular hazards.

In some instances a current exceeding 1 amp may be safe, and in general the current must decrease as the circuit voltage is raised. However, test equipments using several hundred volts have been certified safe.

The British view is that in intrinsic safety they have something to offer the world as an elegant alternative to explosion-proofing, particularly for process instrumentation.

British Positioner

A new automatic coordinate setting system has been designed by Airmec, Ltd. to provide remote control of leadscrews with a resetting accuracy of 0.0003 in. on a 100-in. table. One surprising feature is the low cost of such accuracy: $1,845.

Table position can be set up manually by means of a series of knobs and dials, or automatically by means of punched tape, which contains information for up to 300 operations.

The positioner unit measures the absolute angle of rotation of the leadscrew by means of a coded disc. Basic accuracy is achieved by correcting cumulative errors with a cam in the positioner.

AROUND THE BUSINESS LOOP

Teaching the Teachers

FIER and Case collaborate to help close the technician gap; worthwhile plan still lacks an essential: money.

Convinced that it is just a matter of time before the National Science Foundation approves a grant of $12,000, co-sponsors Case Institute and the Foundation for Instrumentation Education & Research are going ahead with plans for a two-week course in July for 25 post-high-school technical-college teachers. While the NFS weighs their proposal, fast-moving Lloyd Slater, executive director of the FIER and a prime mover in the arrangement with Case, has been marking time in his own inimitable way: he's been writing a book, to be published this spring, all about how you get to the point where you're eligible for the kind of course his foundation and Case have in mind.

There are several extremely interesting things about this course (July 7-25), besides the curriculum, which, incidentally, is no slouch itself when it comes to pulling interest. (Dynamic analysis will be the keypoint, and its use on a theoretical, rather than a hardware basis, the approach.) For example, there is the kind of people who will be enrolled. As of Jan. 15, the sponsors could count on at least two heads of engineering departments (State Technical Institute, Hartford, Conn., and Flint Junior College, Flint, Mich.), one supervisor of electrical engineering education (Pennsylvania State University, University Park, Pa.), one "electrical technology" section head (Oklahoma State University, Stillwater, Okla.), one engineering drawing teacher (Armstrong College, Savannah, Ga.), four instrumentation teachers, and at least eight more teachers of physics, mathematics, and electronics.

• **High on the Hog**—Another point of interest would be humorous if it were not so embarrassingly true: the paid two weeks at Case include $6 per day for living expenses, which is probably more than many of the teacher-students feel free to spend on themselves per day when they are operating on their own salaries.

Slater has been pushing for this kind of course for a long time, in and out of the FIER. He was one of the big guns behind the triggering FIER survey of 90 technical colleges, and he helped select those 25 schools out of the 66 that responded, which will send candidates to Case. His recent contribution to a series of vocational and professional monographs published by Bellman Publishing Co. of Cambridge, Mass., is a step in this same direction. Called *Instrument and Control Engineering*, it takes an informational look at the field of control in what is probably all of its aspects.

Main purpose of the monograph is to pin down the essentials for guidance counselor and students, but as such this purpose actually becomes two-fold: the monograph delineates control, as a field and not simply as a concept, from the standpoints of its structure (what it consists of and what levels of education and skill it demands), its status (users, manufacturers, professional societies, and places of learning) its across-the-board effect on production of all kinds, its job opportunities, and its chances for self-expression.

Sewing Machine Maker Buys Haller, Raymond, Brown

With its purchase of Haller, Raymond & Brown, Inc., The Singer Mfg. Co. brings electronics squarely to bear on the sewing machine. The purchase of HRB from Topp Industries, Inc., which acquired the State College, Pa., R&D firm in 1956, cost Singer $2,075,000, plus $374,000 in repayed advances. Singer will operate it as a division. There will be no changes in personnel, and HRB will continue to be a consultant to many government agencies and industrial firms. A portion of its efforts, however, will now be trained on development of new Singer products.

Bendix Outlet for Fm/fm Will Boost Epsco's Sales

An agreement signed just lately by the Pacific Div. of Bendix Aviation and Epsco, Inc., gives Bendix exclusive sales rights for fm/fm telemetry equip-

See how the facts speak for themselves

hcd* RADIO RECEPTOR Petti-Sel SELENIUM RECTIFIERS *are revolutionizing the field!*

* high current density

► 100,000 hours estimated life ► Lower voltage drop
► Higher current density ► Less reverse leakage
► Smaller size

Standard rectifier

RRco. Petti-Sel rectifier

Both rectifiers are rated at 26V, 8 amps, but notice the significant space saving in the compact Petti-Sel unit.

compare the size...

compare the specs...

STANDARD SELENIUM RECTIFIERS								
NOMINAL CELL SIZE (INCHES)		RRco. CELL CODE	Continuous DC Amperes at 35° C Ambient					
			SINGLE PHASE			THREE PHASE		
Vert.	Horiz.		Half Wave	Center Tap	Bridge	Half Wave	Center Tap	Bridge
1.0	1.0	M	.11	.22	.22	.29	.40	.33
1 3/16	1 3/16	P	.23	.45	.45	.60	.81	.67
1.5	1.5	Q	.45	.90	.90	1.2	1.6	1.3
2	2	S	.70	1.4	1.4	1.8	2.5	2.1
3	3	U	1.6	3.2	3.2	4.2	5.8	4.8
3 3/8	3 3/8	V	2.0	4.0	4.0	5.3	7.2	6.0
4	4	W	3.0	6.0	6.0	8.0	10.8	9.0
4.5	5	G	3.75	7.5	7.5	10.0	13.5	11.2
4 1/4	6	T	4.2	8.5	8.5	11.0	15.0	12.5
5	6	H	5.0	10.0	10.0	13.3	18.0	15.0
6	7 1/4	L	7.5	15.0	15.0	20.0	27.0	22.5

RRco. PETTI-SEL SELENIUM RECTIFIERS								
NOMINAL CELL SIZE (INCHES)		RRco. CELL CODE	Continuous DC Amperes at 35° C Ambient					
			SINGLE PHASE			THREE PHASE		
Vert.	Horiz.		Half Wave	Center Tap	Bridge	Half Wave	Center Tap	Bridge
1.0	1.0	6	0.2	0.4	0.4	0.6	1.0	0.6
1.3	1.3	11	0.5	1.0	1.0	1.5	2.5	1.5
1.6	1.6	16	0.75	1.5	1.5	2.25	3.75	2.25
2	2	25	1.25	2.5	2.5	3.75	6.25	3.75
2.6	2.6	44	2.25	4.5	4.5	6.75	11.25	6.75
4	4	100	4	8	8	12	20	12
4	8	200	8	16	16	24	40	24
4	12	300	12	24	24	36	60	36
8	8	402	16	32	32	48	80	48
8	12	600	22.5	45.0	45.0	67.5	112.5	67.5
8	16	800	30.0	60.0	60.0	90	150	90

In case you haven't noticed, the yellow and gray areas denote actual comparative sizes of the two rectifier types.

and compare the prices! HCD Petti-Sel rectifiers, developed in Western Germany by Siemens and now made in the U.S. by Radio Receptor, offer many important electrical advantages over standard types plus economic advantages.

See for yourself – We'll be glad to send you further information on this remarkable new rectifier line. Submit your requirements to Section C-11R.

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Radio Receptor products for Industry and Government:
Germanium and Silicon Diodes, Selenium Rectifiers, Thermotron Dielectric Heating Generators and Presses, Communications, Radar and Navigation Equipment

WHAT'S NEW

ment incorporating Epsco's special ground-controls "discriminator" for receiving and decoding signals from missiles or aircraft. And it provides minimum sales guarantees to Epsco of more than $4 million over the next few years. Epsco, which in the past apparently helped push its own sales of this equipment, will continue to sell computer linkages and other data-processing components. Last February a major news story told about one of the biggest users of the Epsco equipment (CtE, Feb., pp. 22-28, esp. p. 24).

Stavid and Hoffman Parlay "Smallness" into Big Money

Hoffman Electronics Corp. and Stavid Engineering, Inc., are small companies as control companies go; but they have managed to impress the Federal government with the fact that smallness can be a factor in one's favor when it comes to awarding juicy contracts. The gimmick Hoffman and Stavid have jockeyed so successfully into the big money is intimacy. No prime contractor they say, and have proved it, can get along with its subcontractors like a small prime contractor.

Stavid made its point about six months ago, when it shared with partners Olin Mathieson Chemical Corp., Bausch & Lomb Optical Co., and United Shoe Machinery Co. a contract for development of a defensive anti-missile system (project Dam). A busy government supplier, Stavid just lately received another bouquet: a multi-million contract for guidance systems for the submarine-launched Regulus missile.

It remained for Hoffman, however, to give the contract-sharing plan a name. This came only last January when Hoffman announced its largest contract to-date: an Air Force assignment calling for a complete electronic reconnaissance system, which the company said would be undertaken on a TEAM (Total Engineering and Administrative Management) level. On this level, Hoffman explained, are economics elsewhere unrealizable, because all subcontractors are well-known to each other, and all take part in the preparation and presentation of proposals.

If Stavid and Hoffman come through with their respective projects as successfully as they fully expect to, companies their size may have to be reckoned with as never before when

THOMAS A.

EDISON

current sensitive d.c. relays operate on microamps... carry load of 1/3 amp

This meter-type relay is capable of operating on an input power of 25 microwatts—and on even less power in special applications. When the relay is factory-adjusted for the special conditions to be encountered, sensitivities down to 1 microwatt are possible.

Edison sensitive relays can replace a vacuum tube amplifier in many applications, and offer important savings in weight and cost. Because of their low operating power level, they can be run directly from a thermocouple or photocell output—and are ideal for uses involving servo motors operating from vacuum tube plate circuits. Between the input power to the operating coils and the load capacity of its own contacts, these relays make possible a power amplification factor in excess of 500,000 to 1.

For complete data on Edison Sensitive Relays, write for Bulletin No. 3037.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON

invitations to bid on important jobs are issued.

Census Uses Erasable Tape, But Data Becomes Sacred

Now that it can be filed conveniently for computation, it seems everyone wants to preserve data about the U.S. Census. That's the consensus of the Census, as reported by Sam Alexander of the National Bureau of Standards and relayed to CtE by William H. Chartner of the McGraw-Hill Dept. of Economics. Chartner attended a recent meeting of the New York chapter of the American Statistical Association, which had as a subject the statistical use of computers. Of course, storage techniques were high on the agenda.

One of the advantages of filing Census's very changeable data on magnetic tape, said Alexander, is that the data can be erased when it is no longer useful. But he is meeting opposition. The current cry is: "Erased? Never! Not when you can store away rolls of tape in a fraction of the space it would take you to store punched cards with the same information." The result is, he said, that there are now extant 10,000 rolls of magnetic tape containing Census information, each of which brings down a $50 storage charge.

Alexander went on to tell how computers are being modified to "edit" forms coming into government agencies (i.e., reject those forms that contain basic inconsistencies between the information asked for and that furnished). The only trouble, he observed, is that they are getting too good: they are rejecting about 30 percent of all forms submitted, and each wrong one must be processed manually. The latest word is that instructions are being fed into the computers that will enable them to correct some of the common errors.

New Companies in the Field

Polaris Engineering Corp., a design, development, and consulting firm at home in physics, chemistry, electronics, ballistics, and explosives—in Los Angeles. Thomas C. Bannon is president.

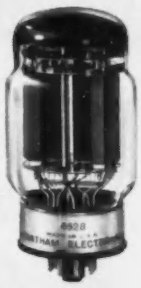
Greenbrier Instruments, Inc., organized by former employees of Watts Mfg. Co. and the West Virginia plant of Beckman Instruments, Inc.—in Ronceverte, W. Va. Major products will be analytical laboratory and proc-

Specialists in special purpose tubes

THYRATRONS—An extensive line of thyratrons for use as grid control rectifiers, relays and noise generators. Inverse voltage ranges from 100 to 5,000 volts. Sizes from subminiatures to ST 16 bulbs. Filamentary as well as hot and cold cathode types are available.

RECTIFIERS—Both vacuum and gas filled tubes with peak inverse voltage ratings from 200 to 15,000 volts. Included are tubes with special features such as fast warm-up, cold cathodes, clipper service ratings and rugged construction.

VOLTAGE REGULATOR AND REFERENCE TUBES—Gas filled tubes designed to specific voltages for regulating small currents. Also used to make available stable reference voltages for high current supplies. Sizes from subminiatures to bantams, including many reliable, ruggedized types.



TWIN POWER TRIODES—The most complete line of high current twin power triodes developed especially for regulated power supply usage. Current and power ranges up to 800 milliamperes and 60 watts respectively. Included are rugged types in both low and medium mu construction.

TELEPHONE TYPES — A highly specialized line of vacuum and gas filled types in both the 300 and 400 series.

HYDROGEN THYRATRONS—Used primarily as switching tubes in line type radar modulators, these tubes permit accurate control of high energy pulses. Sizes from miniatures to the VC 1257. Peak pulse power ranges from 10 kilowatts to 33 megawatts.

Chatham research and development has produced many new tube types that have become industry standards. If you have a special purpose tube problem, Chatham experience can help you find the solution.

CHATHAM ELECTRONICS Division of **TUNG-SOL ELECTRIC INC.**

General Office and Plant: Livingston, New Jersey

SALES OFFICES: CHICAGO, DALLAS, LIVINGSTON, LOS ANGELES

WHAT'S NEW

ess instruments. Sample: an automatic chromatographic analyzer, to be manufactured under a nonexclusive license from Union Carbide Corp. The Beckman contingent at Greenbrier is said to include all the technical personnel of the West Virginia plant.

Moore Associates, Inc., whose namesake appears to be Chief Engineer Laurence Moore, formerly a project engineer with Levinthal Electronics—in Redwood City, Calif. Other officers in the new concern, which will specialize in the development and manufacture of electronic systems: Albert L. Robinson, formerly on the research staff of Bell Telephone Laboratories, president, and James B. Bullock, formerly with Electrical Communications, Ltd., of San Francisco, vice-president.

New Divisions and Groups

An Astronautics Laboratory in the Navigation Projects Dept. of **Kearfott Co., Inc.,** to design guidance and control systems for satellites and space vehicles.

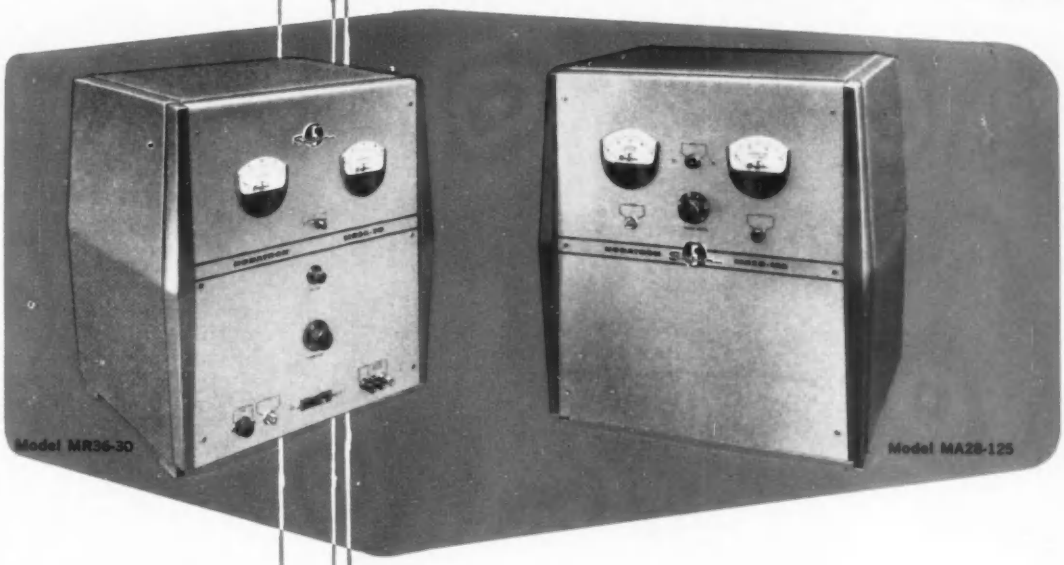
Wiancko Aeronautics, a new division of **Wiancko Engineering Co.** of Pasadena, Calif., to carry this expanding company into fundamental and applied research in high-speed aerodynamics and propulsion. New methods of measurement and test evaluation will also be explored. Manager is H. R. Saffell, formerly director of the Engineering Research Center at the University of Southern California, and chief engineer is C. L. Dailey, formerly chief of the Aeronautics Research Section at the USC center.

Significant changes in Textron's **Dalmo Co.:** Two new departments—microwave and propagation engineering, and servo engineering—in the Engineering Div., supplementing the existing Dept. of Mechanical Engineering; and a brand new Electronic Systems Div. John B. Damonte, formerly assistant director of research, is manager of microwave and propagation engineering; Arthur P. Notthoff, formerly servo-design supervisor, is in charge of servo engineering; and Vice-President Glenn A. Walters, formerly head of research, is manager of the new Electronic Systems Div.

A new Research Center near Fort Lauderdale, Fla., for **Ranco, Inc.,** of Columbus, Ohio, to accommodate an expansion in R&D activities.

An Electronics Div., "a dream shop to promote calm, deliberate thinking", for research personnel of **Taber**

new High Current DC Supplies



Fast Response...High Amps...External Sensing

Model MA28-125
Output: 28 VDC nominal at 125 amps.
Regulation accuracy of ± 0.2%.
Ripple: < 1% RMS.
Response time: < 0.1 second.
Choice of input voltage: 208, 230, or 460 VAC, 3-phase.
Weight: 225 pounds.
$1160 in cabinet.

Model MR36-30
Output current, 0-30 amps, output voltage, 5 to 36 VDC continuously adjustable with regulation ± 0.25% against line or load change.
Response time of 0.2 second.
Input voltage: 105 to 125 VAC, single-phase.
Weight: 175 pounds.
$890 in cabinet.

Also supplied, as Model MR36-15, with output current 0-15 amps, otherwise similar.
Weight: 100 pounds.
$495 in cabinet.

Two new high output power-packs—with response time ranging from 0.2 second down, and with transistorized power reference and magnetic amplifier power control circuits for trouble-free performance—that's just part of the story on these Sorensen DC power supplies.

One model supplies an output of *18 to 36 VDC at 125 amperes;* the other provides 5 to 36 VDC at 0 to 30 amps.

Zener diode reference circuit assures sharper regulation, and the external sensing provision puts this precise control at the load. Silicon power rectifiers and complete tubeless design increase durability with reduction in weight—and greater saving in size.

Get the full story from your Sorensen representative. Or write for technical data.

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WHAT'S NEW

Instrument Corp. of North Tonawanda, N. Y. At present the division is producing a high-pressure transducer for measuring liquid pressure, and a line of transistor amplifiers.

A Research Div. in Van Nuys, Calif., for **Cohu Electronics, Inc.**, formed primarily to investigate building-block design of digital instrumentation systems. Completed systems would be composed of individual devices for measuring stress, strain, temperature, pressure, and other phenomena. In charge of the new division is Martin L. Klein, a prolific writer on electronics (he has 50 papers and two books to his credit).

A new section for **Bendix Aviation Corp.**, to engineer, build, and sell tape-controlled production systems, initially for the aircraft, machine tool, and die-manufacturing industries. Manager of this new Controls Section is George S. Knopf, formerly executive engineer of the Bendix Research Laboratories. Headquarters will be in Detroit.

An Electronic Controls Div. for **General Controls Co.**, to produce high-performance analog servomechanisms for position and velocity control, and transistors and magnetic amplifiers. Heading the engineering team of the division is Fred Marsh.

A Countermeasures group, intended as part of **Sperry Gyroscope Co.'s** Air Armament Div. All activities having to do with electronic jamming equipment, from engineering to purchasing, will be under the management of Norman L. Winter.

Four new divisions for **Clark Controller Co.**: Automation, to deal with integrated control systems for mill drives, processing lines, conveyor systems, and machine tools; Packaged Drive & Control Centers, to handle standard and special packaged speed-control drives; Crane & Mill Accessory Controls, to concentrate on standard and modified control equipment for materials handling, mill auxiliaries, and accessory drives; and Standard Products, to zero in on standard and modified starters, relays, limit switches, etc. R. L. Puette will oversee the first three divisions, R. H. Carlisle the fourth.

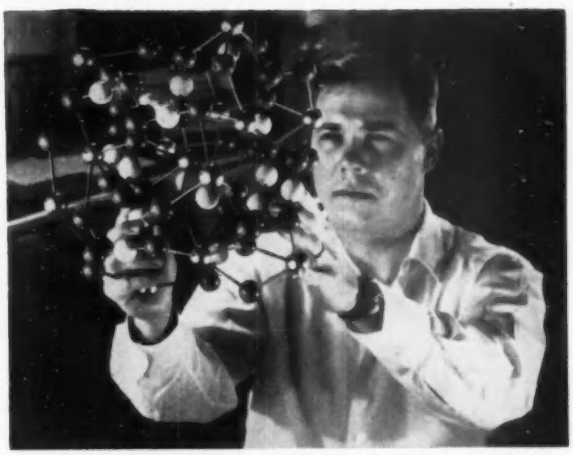
A Stablvolt Div. for **Magnetic Research Corp.**, to manufacture a new line of dc power supplies. Manager C. T. Davis's new group is one phase of an overall company expansion plan.

A Missile Div. formed by **Chrysler Corp.** to direct the company's contributions to the development, engineer-

SYMBOL OF A POWERFUL FORCE

The question mark symbolizes man's inquiring spirit. And nowhere is this spirit cultivated with more enthusiasm than at Bell Telephone Laboratories where, through vigorous research and development, it constantly works to improve electrical communications and also to help national defense in essential military programs.

More than 3000 professional scientists and engineers at Bell Telephone Laboratories are exploring, inventing and developing in many fields: chemistry, mathematics and physics, metallurgy, mechanical engineering, electronics and others. You see the successful results achieved by this organization of inquisitive and highly trained minds in the nationwide telephone system that serves you.



Dr. Walter Brown, physics graduate of Duke and Harvard Universities, bombards crystalline solids with one-million-volt electrons to study the nature of simple defects in crystals. Objective: new knowledge which may help improve transistors and other solid state devices for new and better telephone and military systems.

Peter Sandsmark, from Polytechnic Institute of Brooklyn, and his fellow electrical engineers develop a new microwave radio relay system able to transmit three times as much information as any existing system. Objective: more and better coast-to-coast transmission for telephone conversations and network television.

Bill Whidden, from Polytechnic Institute of Brooklyn, and George Porter, from Georgetown College, study new experimental telephone instruments designed to explore customer interest and demand. Objective: to make your future telephone ever more convenient and useful.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

WHAT'S NEW

ing, and production of the Redstone and Jupiter missile programs. Increased participation in these programs was the reason given for establishment of a specific division to carry out the work. Chrysler has been associated with Army ballistic missile work since 1952. Irving J. Minett, who heads the Defense Operations Div., is group executive in charge of the new unit. His general manager is C. Allan Brady, who has been operating manager of Chrysler missile operations for the last two years.

An Industrial Products Div., formed by **Hill Transformer Co., Inc.**, of San Carlos, Calif., to build special-duty transformers. Principal target: guided-missile ground-control systems.

Two new divisions (Instrumentation and Audio Products) for **ORRadio Industries, Inc.**, the fast-growing instrumentation-tape maker located in the deep south (Opelika, Ala.). James D. Grady Jr. will manage the first division, and Robert D. Browning, a former chief recording engineer for RCA-Victor, will be in charge of the second.

A new group, Daystrom-Weston Co., made up of these divisions of **Daystrom, Inc.**: Weston Instruments, Daystrom Systems, and Daystrom-Weston Industrial. Thomas Allinson, who came to Daystrom from Beckman Instruments, Inc., last year, takes over the new group as president and chief operating executive while continuing as a Daystrom vice-president. In his words, the move represents "a streamlining of our organization to provide a single source with full responsibility for industrial electronic instruments and process controls". Earl R. Mellen, formerly president of Weston, is chairman of the group; Rosewell W. Gilbert, formerly on the Daystrom executive staff, is vice-president for R&D, and John H. Miller, formerly a Weston vice-president, is vice-president and technical advisor to the president.

The Weston Instruments Div., incidentally, is the successor to Weston Electrical Instrument Corp., a Daystrom subsidiary that was merged into the parent company just a week before the new group was formed. In charge of the division under the new program will be Walter W. Slocum, executive vice-president and general manager. The Daystrom-Weston Industrial Div. will be the responsibility of James F. Brehm, vice-president and general manager; and the Daystrom Systems Div. will continue under Chalmer E. Jones, general manager.

STANDARD CAPACITORS

are manufactured from high-quality materials

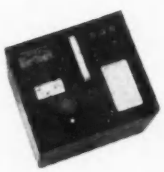
to insure: LOW TEMPERATURE COEFFICIENT
LOW DIELECTRIC LOSS
LOW DIELECTRIC ABSORPTION

...and are carefully assembled, inspected, and calibrated under ASTM standard laboratory conditions of temperature and humidity

to insure: HIGH STABILITY
HIGH ACCURACY

VARIABLE CAPACITANCE STANDARDS

Type 722 is a Precision Variable Capacitor mounted in a cast aluminum frame for rigidity. Capacitor supports are of low-loss steatite — can be supplied with silicon-treated quartz supports on special order. Accurate machining of worm and gear drive virtually eliminates back lash. Dial may be precisely set to 1 part in 25000. Linear scale length is 19.2 feet.



Type	Range ($\mu\mu$f)	Accuracy	Reads
722-D $235	100 to 1150 25 to 115	±0.1% or ± 1$\mu\mu$f* ±0.1% or ±0.2$\mu\mu$f*	Total Capacitance
722-MD $225	0 to 1050 0 to 105	±0.1% or ± 1$\mu\mu$f* ±0.1% or ±0.2$\mu\mu$f*	Capacitance Removed (for bridge substitution measurements)
722-ME $225	0 to 105 0 to 10.5	±0.1% or ±0.2$\mu\mu$f* ±0.1% or ±0.05$\mu\mu$f*	
722-N $210	100 to 1150	±0.1% or ± 1$\mu\mu$f* *whichever is the greater	Total Capacitance (recommended for r-f use — lower metallic resistance and inductance)

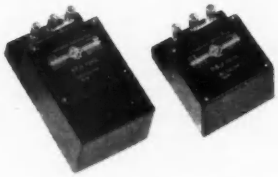
Correction chart supplied permits greater accuracy — additional correction chart for residual eccentricity of worm drive furnished on special order.

FIXED CAPACITANCE STANDARDS

Type 1401 is an air-dielectric capacitor adjusted to ±(0.1% + 0.1$\mu\mu$f) accuracy.

Type	Capacitance	Dissipation Factor	Price
1401-A	100$\mu\mu$f	<0.00004	$45
1401-B	200$\mu\mu$f	<0.00003	$46
1401-C	500$\mu\mu$f	<0.00002	$48
1401-D	1000$\mu\mu$f	<0.00001	$53

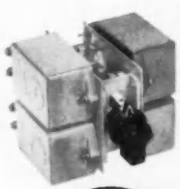
Type 1409 Standard Capacitor utilizes silvered mica and foil-stack construction. Units are aged to insure accuracy and stability. Dissipation factor is less than 0.0003 when measured at 1 kc and 23°C. May be used for either 2- or 3-terminal measurements.



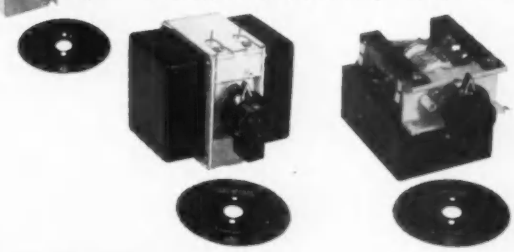
Type	Capacitance, μf	Price
1409-F	0.001	$32
1409-G	0.002	$32
1409-K	0.005	$34
1409-L	0.01	$34
1409-M	0.02	$36
1409-R	0.05	$39
1409-T	0.1	$42
1409-U	0.2	$50
1409-X	0.5	$80
1409-Y	1.0	$1.0

DECADE CAPACITORS

Type 980 Decade Capacitor Unit is an assembly of high-quality capacitors mounted on an eleven-point switch to give a total capacitance variation of 10:1 in ten equal increments. All increments are accurate to within ±1% except the Type 980-L which is within ±2%, and the Types 980-F, -G, and -H, which are ±0.5% units. Zero capacitance of all units is 10$\mu\mu$f.



Type	Capacitance	Dielectric	Dissipation Factor at 1 kc and 23°C	Price
980-A	1.0μf in 0.1μf steps	Polystyrene	<0.0003	$66
980-B	0.1μf in 0.01μf steps	Polystyrene	<0.0003	51
980-C	0.01μf in 0.001μf steps	Polystyrene	<0.0003	57
980-F	1.0μf in 0.1μf steps	Mica	<0.0005	132
980-G	0.1μf in 0.01μf steps	Mica	<0.0005	60
980-H	0.01μf in 0.001μf steps	Mica	<0.0005	45
980-L	1.0μf in 0.1μf steps	Paper	<0.010	36
980-M	0.1μf in 0.01μf steps	Molded Mica	<0.001	42
980-N	0.01μf in 0.001μf steps	Molded Mica	<0.001	32



DECADE BOXES

are assemblies of Type 980 units, and are available in a variety of dielectrics to meet the needs of either general purpose or critical measurements. All units are 1.110μf maximum in steps of 0.001μf.

Type	Type 980 Decades used	Dielectric	Remarks	Price
1419-A	A, B, C	Polystyrene	for 2- or 3-terminal measurements	$205
1419-K	F, G, H	Mica		270
219-M	L, M, N	Paper & Molded Mica	2-Terminal Only	135

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WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

▶ Worcester Polytechnic Institute has named **Glen A. Richardson,** formerly associate professor of of electrical engineering at Iowa State College, head of the EE Dept. He succeeds **Theodore H. Morgan,** in charge of the department since 1931, who will continue as EE professor. Morgan came to the Worcester faculty in 1931 from Stanford; he had been executive head of the EE Dept. there.

▶ Of six new vice-presidents of the Taylor Cos., three are directly concerned with engineering. They are: **Nathaniel B. Nichols,** chief engineer; **William Walters,** head of manufacturing, and **Karl Hubbard,** in charge of research. Before joining Taylor, Nichols taught electrical engineering at the University of Minnesota; before that he was affiliated with Raytheon Mfg. Co. and MIT's Radiation Laboratory. Walters came to Taylor in 1936. Hubbard, who joined in 1928, was chief engineer and technical director before becoming research director.

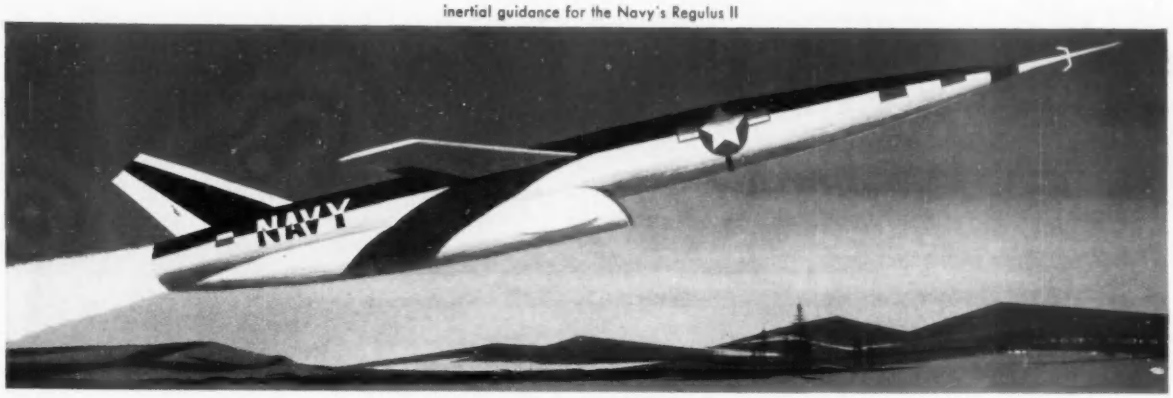
▶ **Charles F. Taylor,** well-known for his work in nonlinear adaptive control, has been promoted by Daystrom's Systems Div. to head of the Systems Analysis Group. He will direct analytical and mathematical formulations and applications of systems in industrial process control. Before joining Daystrom, Taylor was connected with the Air Force's Cambridge Research Center.

▶ **A. James Edwards** has been appointed general sales manager for Electro Precision Corp. of Arkadelphia, Ark. He joins the company from General Electric's Flight Propulsion Laboratory, where he was in charge of the sale of jet engine controls. His other prior affiliations are all top instrument and control companies: Mid-Century Instrumatic Corp., Satullo Co., and Brush Electronics.

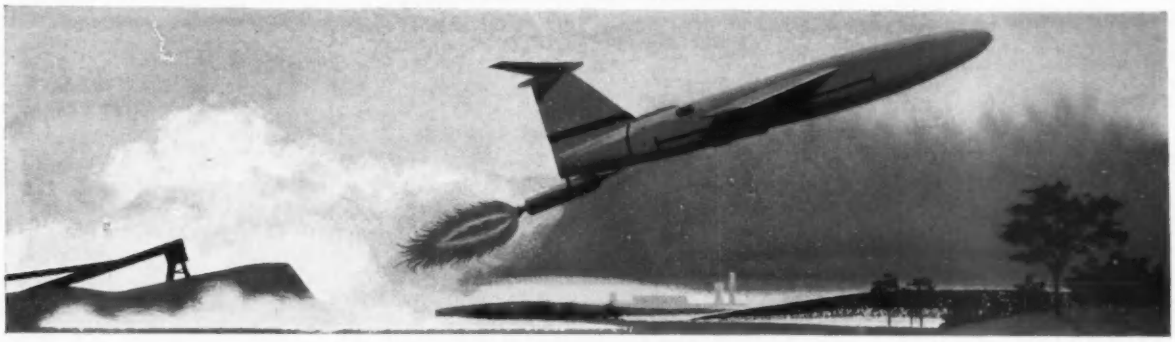
▶ The new chief engineer of Neff Instrument Corp. is **Richard A. Shaw,** formerly with the Alectra Div. of Consolidated Electrodynamics, and before that with Collins Radio Co.

▶ Waltham Precision Instrument Co., formerly Waltham Watch Co., has named **Andrew C. Bayle** director of engineering. Bayle has made a name for himself in the precision electromechanical and electronic fields, particularly in gyroscopic instrumentation and servomechanisms, as assistant to the president of Vectron, Inc.,

inertial guidance for the Navy's Regulus II



the brain behind the accuracy of the Martin Mace



now in use on the Air Force's Thor intermediate range ballistic missile

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It takes all the technical know-how of American industry to produce gyroscopes in volume to the quality standards needed for inertial guidance systems. The sensitivity of the gyro-accelerometers (used to sense the slightest deviation in flight) is the key to the success or failure of the missile. AC gyro-accelerometers are setting the world's highest standards of quality . . . meet minimum tolerances required . . . and they have withstood as much as 5,000 to 7,000 hours of operation without significant loss of efficiency. Gyros available for immediate delivery: 75×10^6; 10×10^6; 2×10^5; 1×10^4.

—If you are an engineer with electrical, mechanical or electronic backgrounds, contact Mr. Cecil Sundeen, Supervisor of Technical Employment, Dept. H, in care of AC . . . the Electronics Division of General Motors, Milwaukee 1, Wisconsin.

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WHAT'S NEW

chief engineer of Doelcam Corp., and research engineer at MIT.

▶ **W. F. Eagan,** the new chief engineer of Allis-Chalmers' Control Dept., joined the company in 1947 and for the last eight months has been in charge of control engineering. Before that, he supervised regulator engineering and circuit development in the Control Dept.

▶ **Edward E. Kirkham** has taken over the Experimental Dept. of Pratt & Whitney's Machinery Div. as chief development engineer. He joined P&W shortly after the war, left later to go to Federal Electric Products Co. of Hartford, Conn., and returned in 1953 as a project engineer. He has been closely connected with P&W's numerical control developments, primarily the punched-tape metal-working system described recently (CtE, Jan., p. 75).

▶ Milton Roy Co. has promoted **Richard A. Bennett,** formerly design engineer, to chief mechanical research and development engineer. As such, he will be in charge of the new mechanical-product area, which includes controlled-volume pumps, enclosed drives, and chemical relief valves. He came to the company in 1953 after experience with American Pulley Co. and du Pont. The new product engineering manager is **John P. Klembeth,** assistant chief engineer since last year and with Robertshaw-Fulton Controls and Minneapolis-Honeywell before that.

▶ Westinghouse has named **George F. Mechlin Jr.** director of advanced systems engineering in the Sunnyvale Div. and **Donald W. Gunther** manager of the Semiconductor Dept. at Youngwood, Pa. Mechlin, who succeeds the late **Weldon H. Brandt,** will direct special studies related to experimental handling and launching systems for the Polaris missile. He has been with the company since 1949, first as a senior scientist in experimental physics, then as supervisory scientist on the submarine fleet reactor project, and most recently as manager of this project's physics subdivision. Gunther, who has been manager of the Materials Engineering Dept., joined the Westinghouse training program in 1940.

▶ Electro Tec Corp.'s new director of engineering is **A. J. Talamini Jr.,** formerly chief engineer of the Technical Products Div. of A. B. DuMont Laboratories. An electronics specialist, Talamini has also been with Federal Radio, RCA, and Kolarama Laboratories. He is a senior member of the American Rocket Society.

Perkin-Elmer Corp. has named **R. Victor Harris** general manager of the Instrument Div., succeeding **Van Zandt Williams** (CtE, Feb., p. 176).

W. F. Eagan

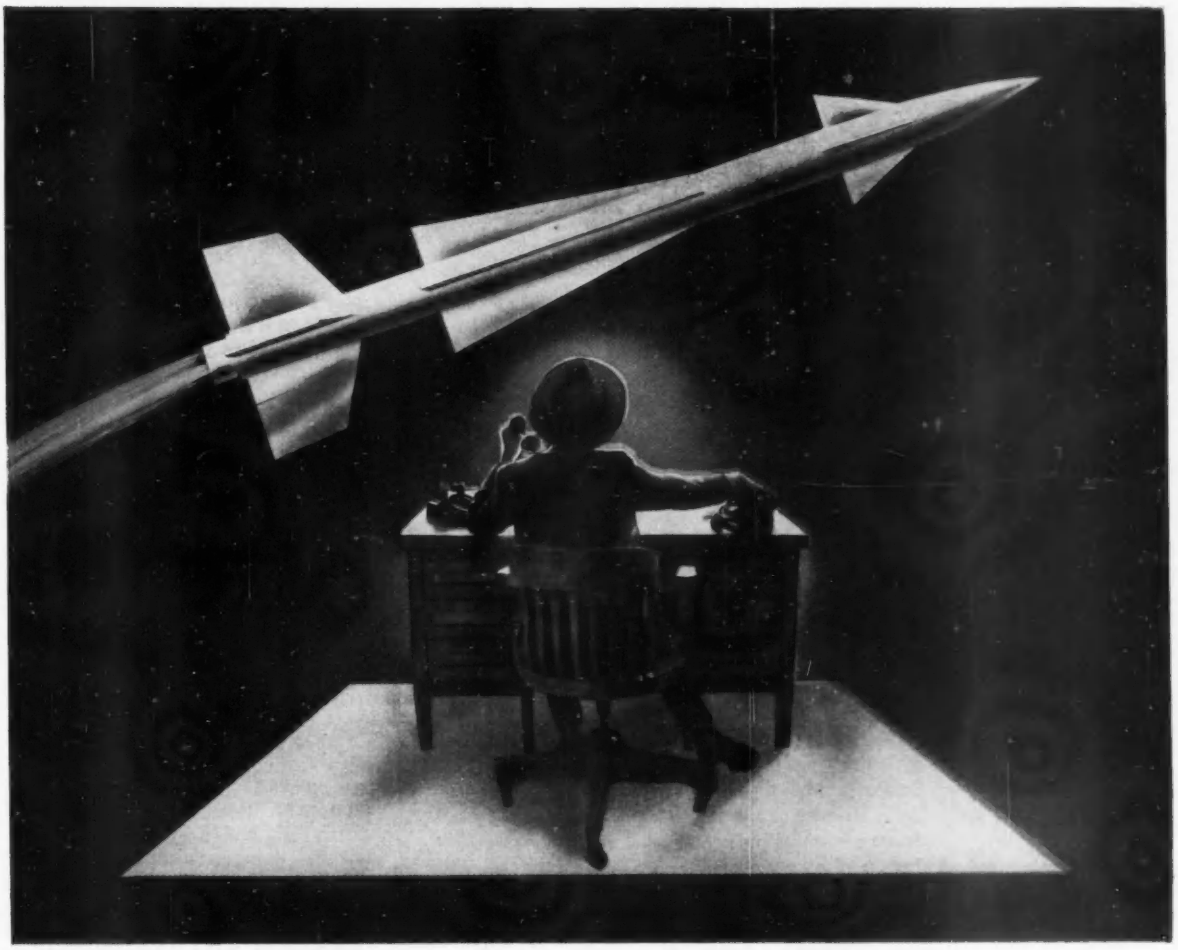
E. E. Kirkham

R. A. Bennett

G. F. Mechlin Jr.

A. J. Talamini Jr.

R. V. Harris



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DAYSTROM INSTRUMENT

Division of Daystrom Inc.

ARCHBALD, PENNSYLVANIA

WHAT'S NEW

Harris joined P-E in 1949 and became director of production in 1950 and assistant manager of the Instrument Div. in 1956. His previous experience was with Taylor Instrument Cos. and the MIT Radiation Laboratory.

▶ **Markus M. Epstein** is the new chief engineer of Control Electronics Co., Inc. His previous experience was with Empire Devices, Inc., the Fairchild Pilotless Plane Div., Bell Aircraft Corp., and Lewt Corp.

▶ Waldorf Instrument Co. has named **Everett Gravenhorst** director of engineering in the Fluid Systems Div. He comes from The Martin Co., where he was chief mechanical engineer. Earlier, he had been supervisor of hydraulic design at Air Associates. He is a recognized authority on flight controls, hydraulic and pneumatic power systems, and alighting gear equipment.

▶ **Paul Petrack** has been appointed chief engineer for semiconductors in the Components Div. of International Telephone & Telegraph Corp. He joined the company last year from Radio Receptor Co., where he had been manufacturing and engineering manager.

▶ **Louis N. Ridenour,** in charge of research for Lockheed's Missile Systems Div., is doing a second hitch as a member of the Air Force Scientific Advisory Board. His first tour of duty: 1948-1952. During this period he chairmanned a committee to survey Air Force R&D activities. That committee prepared the report that led to the establishment of the Air Research & Development Command and the office of deputy chief of staff for development.

Obituaries

Louis A. Durgin, 45, senior engineer at Allen B. Du Mont Laboratories, Inc. His home was in Pines Lake, N. J.

B. E. Eisenhour Sr., who invented the bimetallic, temperature-compensated tuning fork while associated with Riverbank Laboratories of Geneva, Ill. He retired from Riverbank as chief engineer in 1956.

F. E. Ericson, formerly president of The Barden Corp., maker of precision ball-bearings, in Danbury, Conn. He retired in 1956.

William G. Chenoweth, 32, senior engineer in charge of high-frequency measuring equipment at the Berkeley Div. of Beckman Instruments, Inc. Death was due to injuries received in an auto accident.

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Bug hunting . . . failure testing . . . safety factors . . . flight testing—none of these traditional reliability concepts is sufficient to insure maximum performance of missile guidance systems.

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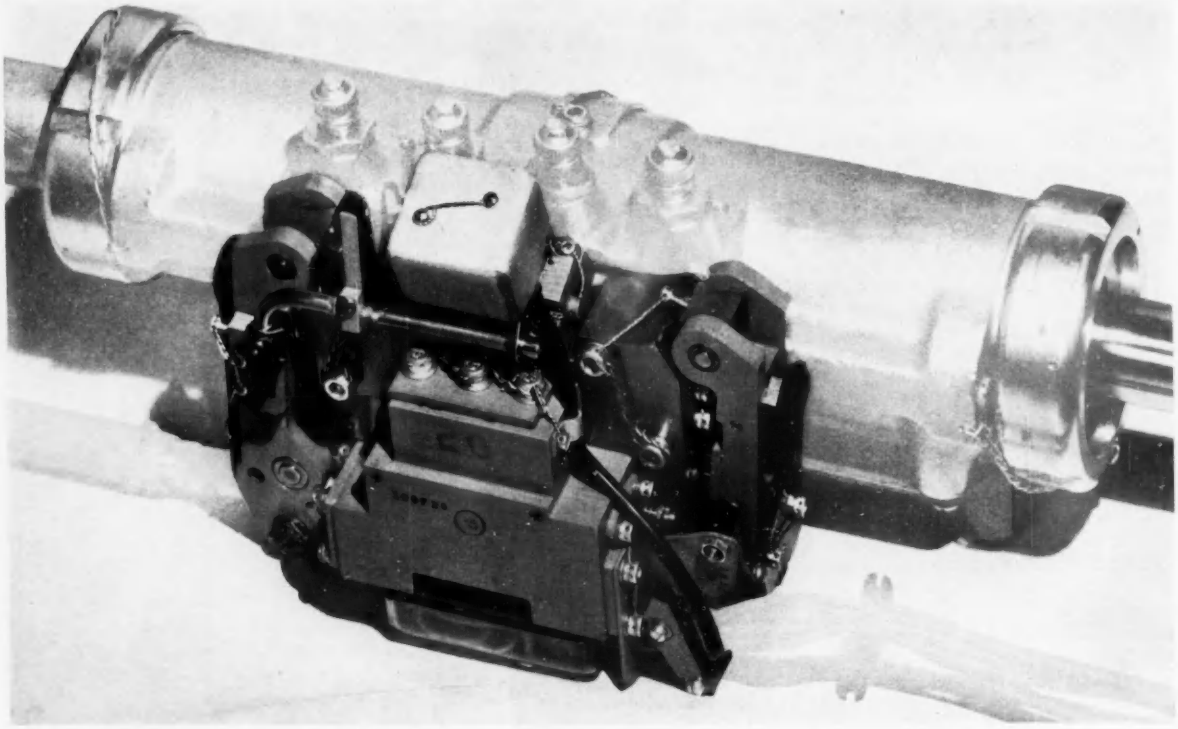
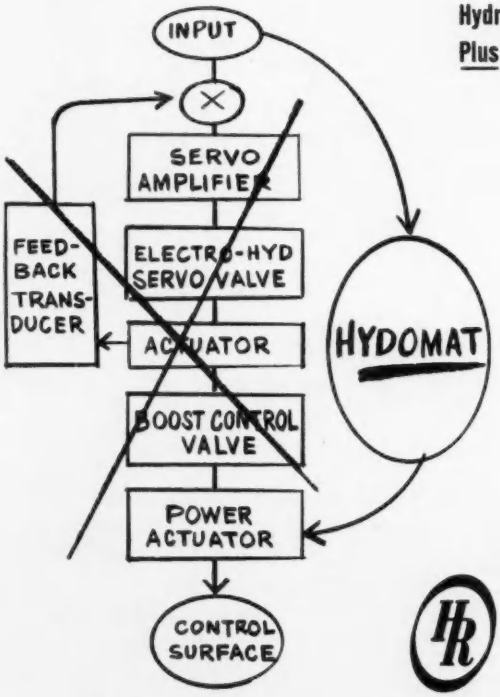


"Hydomat" cuts 27 pounds off Standard Aircraft Control System



Hydraulic Research's System Eliminates 9 lbs. of Components Per Axis, Plus 10-50 lbs. of Plumbing and Structure Without Sacrifice of Function

The Hydomat is a powered flight control servo system of the multiple input type designed for control of a tandem hydraulic cylinder. It will accept mechanical signals created by the pilot, as well as electrical control signals created by electronic amplifiers. Means are provided to remotely select the signal source to obtain the following modes of operation:

1. **Manual:** Mechanical signals operate the valve in the conventional power control manner.
2. **Autopilot:** Electrical signals operate the valve as a conventional electro-hydraulic servo valve.
3. **Damper:** Mechanical signals operate the valve as in the manual mode with superimposed electrical signals to provide damping for improved airframe stability.

For flight safety provision is made for full mechanical override of the electrical signal.

Hydomat modifications are currently in use in missile control systems also.

Write for complete performance data.

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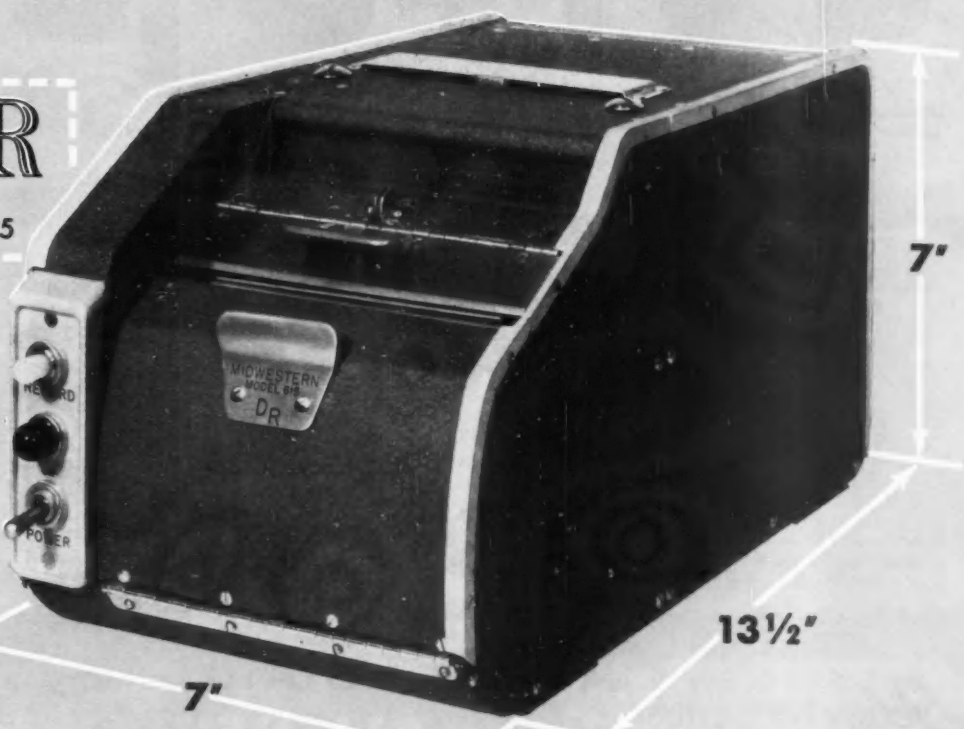
D/R

MODEL 615



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No Chemical Processing!

The 615 D/R is a small, compact and economical version of Midwestern's large 602 D/R and retains many of its outstanding features.

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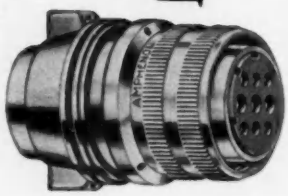

Smallest environmentally resistant MIL-C-5015C MS "E" connectors.

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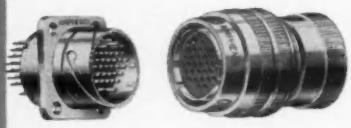

Miniature MS "E"-type connectors. A complete family of miniatures.

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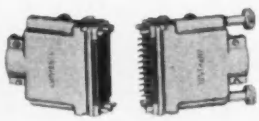
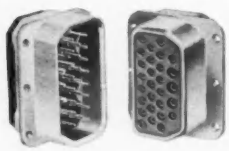
Subminax RF connectors for RG-196/U. Field serviceable, new cable clamp.

93 SERIES



Versatile line of Rack & Panel connectors with Poke Home* contacts.

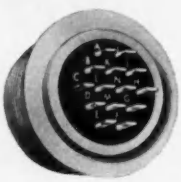
94 SERIES



Polarized-shell Rack & Panels with Poke Home* contacts. Complete line.

*Crimp-type contacts that are wired outside the connector and Poked Home for assembly

Identoseals



Hermetic Seal MS-type receptacles with contact identification on the insert.

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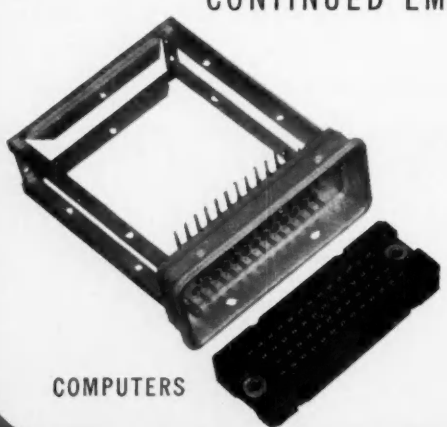
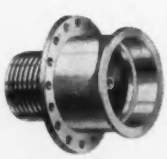
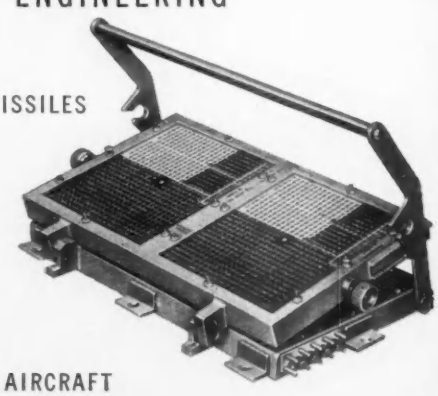


COMPUTERS



MISSILES



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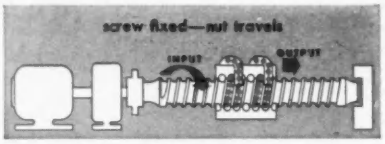
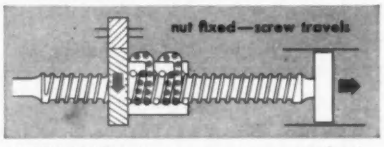


NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on rolling steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls, converting rotary force and motion to linear force and motion with unprecedented efficiency.

An unprecedented achievement in minimum size and weight—maximum efficiency, dependability and service life for ultra-precise controls.

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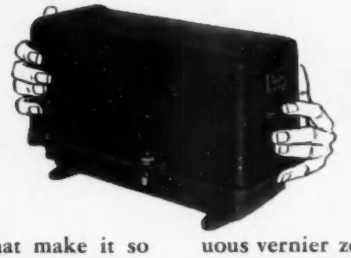
TAYLOR POTENTIOMETER TRANSMITTERS

CALIBRATED TO YOUR SPECS.



NOW we can offer you immediate delivery of the 700T Taylor TRANSET* Potentiometer Transmitter—custom-equipped for your specific application. **It's the unique** plug-in features of this instrument—plug-in amplifier, plug-in transducer, plug-in service "cans"—that make it so superior and so readily adaptable to your needs. *And it's these same benefits of flexibility that permit us to fill your orders so promptly.*

Plug-in service "cans" means that the instrument can be quickly adapted for use with different primary elements by simply plugging in the corresponding can. (For thermocouple applications cold junction compensation is provided in the can).

Just one amplifier. You change its service by switching service cans. Both the amplifier and the transducer plug-in . . . means minimum instrument down-time for service. Also means low instrument inventory because you only need one spare amplifier.

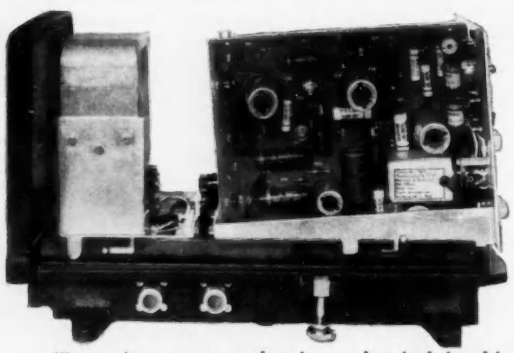
*Reg. U.S. Pat. Off.

Check these additional benefits: • Infinitely sensitive to input signal. • High order of linearity and accuracy. • No moving parts such as slidewires, batteries, or standard cell. • Continuous vernier range adjustment. • Continuous vernier zero or suppression adjustment. • Convenient front panel checkout and adjustment. • Printed circuit, for completely uniform performance. • Thermocouple burnout protection, either up or down scale.

Acknowledged by users as the finest instrument of its kind on the market, the TRANSET Potentiometer is ideal for processes permitting the use of pneumatic receivers and controllers, whether large case or miniature. Its outstanding flexibility permits a narrow or wide range span according to process demands.

• • • •

Call your Taylor Field Engineer, or write for **Catalog 98262.** Taylor Instrument Companies, Rochester, N.Y., or Toronto, Ontario.



Transmitter converts a dc primary electrical signal into a 3-15 psi pneumatic output for controllers and receivers.

INSTRUMENTS IN STOCK WITH THESE PRIMARY ELEMENTS

THERMOCOUPLE . . . *Copper-Constantan . . . Iron-Constantan . . . Chromel-Alumel*

VOLTAGE . . . *For pH; strain gages; tachometers; 0-50 mv.*

Taylor Instruments MEAN ACCURACY FIRST

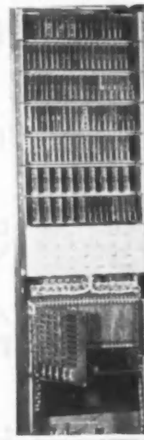
FROM CORES TO COMPLETE MEMORIES











1 Die-forming of cores
2 Special furnaces for ceramic firing
3 18,000 cores graded per hour by special equipment
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5 Production aids speed matrix assembly
6 Electronic test of completed matrix
7 Core matrix for a digital computer
8 Inspected matrices form complete storage module
9 TMI memory for ERMA computer

SPECIFY CORE TYPE:
- 80T5 for medium speed, transistor driver memories
- 80T1 for high speed, tube driver memories
- 80T1B for high speed, transistor driver memories
- 50T1 for super-speed, tube or transistor driver memories
- 180T5 for core switching application

UNDER ONE ROOF. At Telemeter Magnetics, Inc., ferrite core production and their end use are fortunately often merged into one functional design solution. *Core* production facilities work intimately with design engineers to produce magnetic cores of top quality at mass production rates. With this thorough grounding in magnetic core technology, TMI manufactures core *matrices* in a wide range of configurations and offers core arrays to individual customer needs. Core matrix assembly is done by highly trained production personnel and each matrix is tested under marginal conditions by special test equipment. With their own *cores, arrays* and *storage modules,* TMI has produced a series of *buffer storage* systems and random-access *memories* for General Electric, Remington Rand, ElectroData Division of Burroughs Corporation and others. If your problem involves ferrite cores, core matrices, or core storage systems, consult TMI first.

write for company brochure to: Dept. CE4

TELEMETER MAGNETICS *Inc.* 2245 Pontius Avenue, Los Angeles 64, Calif.

4237

NOW! END READOUT CONFUSION...

with the new KIN TEL digital voltmeter

ANOTHER FIRST FROM KIN TEL! Here is a digital voltmeter that shows numbers on a readable single plane! With KIN TEL's new design, there are no superimposed outlines of numbers in the picture...no confusion caused by dials and old style numerical readouts. This digital readout uses a simple projection system – provides 7,000 to 8,000 hours of lamp life, compared with 100 to 200 hours for ordinary readouts.

FIRST OF A COMPLETE LINE OF DIGITAL INSTRUMENTS! Others include: Converters for measuring AC, ohms, ratios...multiple input scanners... serial converters to drive typewriters and punched tape units.

WIDE APPLICATION! KIN TEL digital instruments are ideal for automatic check-out systems for missiles and rockets; computer measurements; process control monitoring; production testing; test system calibration; strain gage, thermocouple and other transducer measurements, and calibration of laboratory and industrial electronic instruments.

Talk to your local KIN TEL representative. Sales and service everywhere. Or write us direct for further information.

See the difference!

ORDINARY READOUT

KIN TEL READOUT

CLEAR AND SHARP, ANY WAY YOU LOOK AT IT

- *100 Microvolt Sensitivity*
- *Automatic, Continuous Standard Cell Calibration*
- *High Reliability*
- *0.0001 to 999.9V–Plus Automatic Decimal and Polarity Indication*

SPECIFICATIONS

Display...Four (4) digit with automatic polarity indication and decimal placement. Total display area 2" high x 7.5" long, internally illuminated. Individual digits 1.25" high.

Automatic Ranges...0.0001 to 999.9 volts covered in four ranges.

Accuracy...0.01% or 1 digit, whichever is larger.

Counting Rate...30 counts per second, providing average balance (reading) time of 1 second, maximum balance time of less than 2 seconds.

Reference Voltage...Chopper-stabilized supply, referenced to an unsaturated mercury-cadmium standard cell.

Input Impedance...10 megohms, all ranges.

Output...Visual display, plus print control. Automatic print impulse when meter assumes balance. No accessories required to drive parallel input printers.

Input...115 volt, 60 cycle, single phase, approximately 75VA.

Dimensions...Control unit, 5¼" high x 19" wide x 16" deep. Readout display, 3½" high x 19" wide x 9" deep.

Weight...Approximately 40 lb.

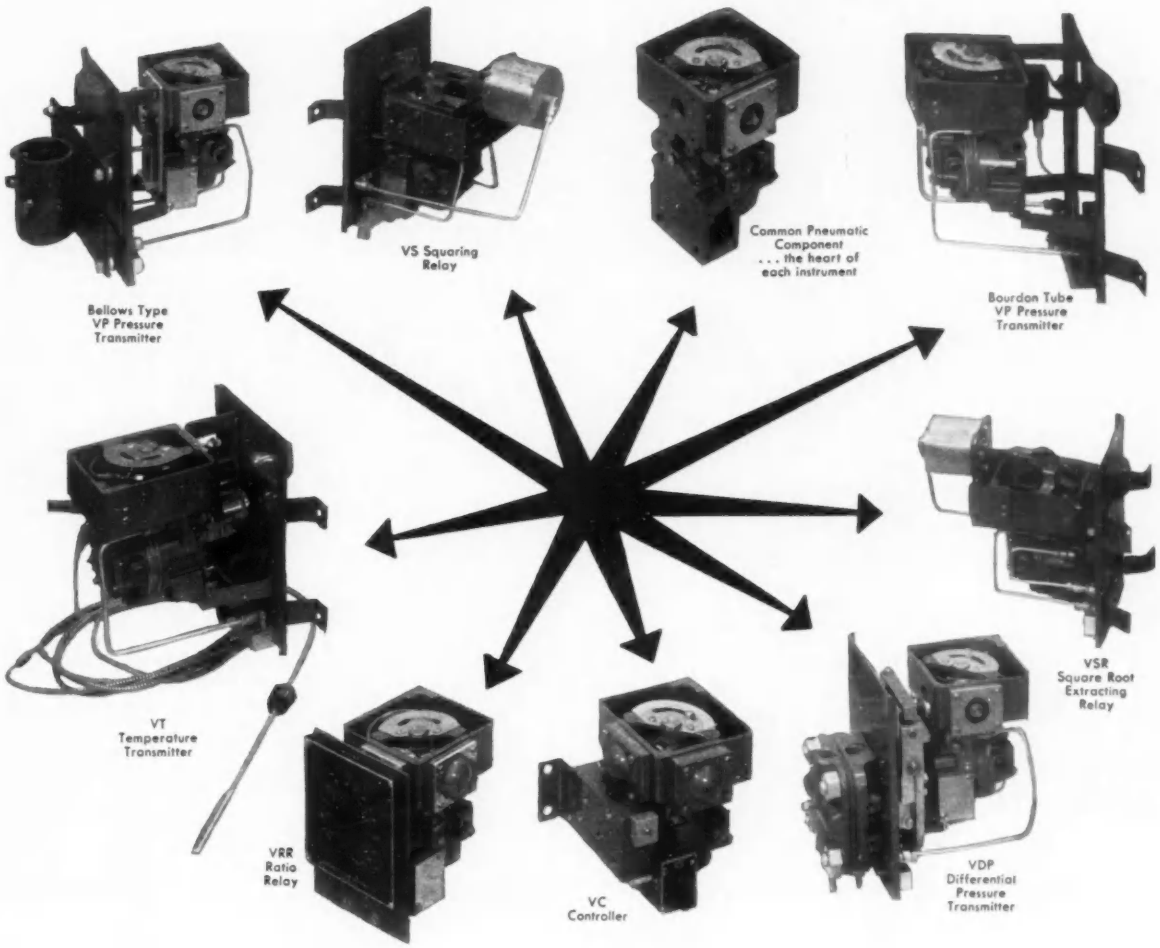
Price...$2,100

Over 10,000 KIN TEL instruments in use today!

KIN TEL

A Division of Cohu Electronics Inc.

5725 Kearny Villa Road
San Diego 11, California



It's YOUR move—in ANY direction—with

Republic's New Family of Null-Balance-Vector Instruments

Here are only a few of Republic's new line of pneumatic instruments. Their sensitive, extremely accurate components are both compact and interchangeable. Their versatility is phenomenal. Consider: the Vector Series components in *each* of these instruments can be moved and *recombined in infinite variety*. They form temperature transmitters with 10-to-1 range adjustment . . . pressure transmitters of ±0.5% accuracy . . . differential pressure transmitters with 20-to-1 range adjustment . . . controllers which feature repeatable re-set rate, less than 0.05% dead band and proportional band adjustment from 2 to 500%.

The span of each instrument can be varied at will; only a screwdriver and a reference are necessary—zero need not be re-set. Republic's Null-Balance-Vector design permits full-range operation with virtually no parts motion—and virtually no wear.

This new family of pneumatic instruments was developed in a coordinated program to use the greatest possible number of common components. Because these can be interchanged, even among instruments performing entirely different functions, training and spare parts problems are greatly simplified. The versatility of Republic components is at once a challenge and an answer to imaginative engineers. A few minutes of discussion on this subject could be well worthwhile . . . and a call to your nearest Republic Sales Office will set it up at your convenience.

For detailed, descriptive folios write

REPUBLIC
FLOW METERS CO.

Subsidiary of ROCKWELL MANUFACTURING COMPANY
2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
In Canada: Republic Flow Meters Canada, Ltd.—Toronto

Manufacturers of electronic and pneumatic instrument and control systems for utility, process and industrial applications.

MICROAMMETER-MILLIVOLTMETER RECORDER PERFORMS 6 FUNCTIONS

1. **Measures low-level dc signals with calibration accuracy within 0.5%, and sensitivity within 0.2% of span.**
2. **Records on 3" continuous strip chart or IBM-type card chart, with linear coordinates.**
3. **Positions recording pen with force many thousand times greater than usual direct-deflection electrical movements.**
4. **Operates on force-balance principle—compensates for ambient conditions, changes in power supply and components.**
5. **Records fast—up to 0.05 seconds for 63% of fullscale changes.**
6. **Provides span and zero adjustments for easy calibration and zero suppression in the field, without special equipment.**

For only $250— A More Accurate HIGH-SPEED MILLIVOLT RECORDER

This highly sensitive 'American-Microsen' Series 130 Recorder, with all its operational advantages, costs less than others designed for the same jobs. Simple design, precision components and rugged construction assure sustained high accuracy and freedom from maintenance. The recorder withstands shock up to 30 times gravity.

Since its introduction less than a year ago, the Series 130 Recorder has been very successful because it offers a more accurate and durable method of recording dc electrical signals at lower cost. It is being used to record outputs of many different electrical transducers – for measurement of such variables as pH, gas analysis, signal strength and others.

Many laboratories have adapted the Series 130 Recorder to their analytical and scientific instruments to assure accurate, permanent records of results which previously were only indicated. The Recorder can be used with any device which can provide 200 microamperes or more in its output circuit.

Standard 'American-Microsen' Series 130 Recorders are priced at $250.00. All models have ample power to operate alarm contacts which can be supplied at extra cost. *Write for Bulletin MG10.*

SPECIFICATION BRIEFS

POWER SUPPLY: 115 volts, 60 cycles. **POWER REQUIREMENT:** 9 watts.

INPUT RANGES: Voltage – 0-20 millivolts to 0-100 volts dc. **Current** – 0-200 microamperes to 0-100 milliamperes dc. **Input Sensitivity** – 6700 ohms per volts.

ACCURACY: ± 0.5% of span. **SENSITIVITY:** ± 0.2% of span.

REPEATABILITY: ± 0.25% of span.

EFFECT OF SUPPLY VOLTAGE: Less than 0.5% error 90-130 volts.

EFFECT OF AMBIENT TEMPERATURE: Less than 0.5% error 50° to 100° F., and less than 1% to 130° F.

RESPONSE TIME: Fast Speed – 0.2 seconds standard for 63% of fullscale input change; up to 0.05 seconds for 63% on special order. **Slow Speed**– approximately 4 times fast speed setting.

CHART SPEEDS: Strip Chart – 1" per hr., standard; 3" or 6" per hr. available. **Card Chart** – 1 rotation per day, standard.

SPAN ADJUSTMENT: ± 10% of span. **ZERO ADJUSTMENT:** ± 100% of span.

PANEL SPACE REQUIRED: Only 27 square inches.

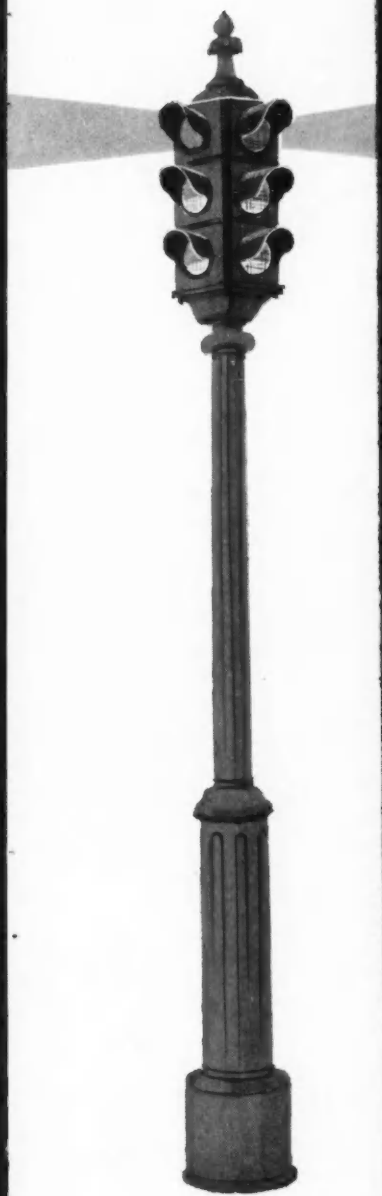
MANNING MAXWELL & MOORE INC. MM&M TRADE MARK

MANNING, MAXWELL & MOORE, INC.

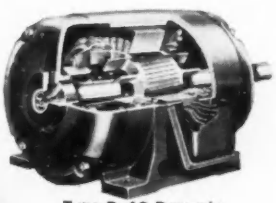
INDUSTRIAL CONTROLS DIVISION · DANBURY, CONNECTICUT

MAKERS OF 'AMERICAN-MICROSEN' ELECTRONIC INSTRUMENTS FOR MEASUREMENT, TRANSMISSION AND CONTROL

MI-58



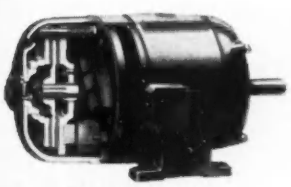
GIVE YOUR PRODUCTS THE BEST OF BRAKES!



Type D, AC Dynamic

ROLLING STOP... Master Type D Dynamic Unibrake Motors. Braking is obtained with a unique, patented brake winding superimposed on the stator winding. Simple, compact, with no DC current required, the brake has no moving parts. There is nothing to wear or adjust... braking torque repeats consistently. Particularly recommended for automatic applications where static holding is not desired. Sizes ¼ to 30 H.P.

MASTER UNIBRAKE MOTORS



Type M—Magnetic

STOP-HOLD... Master Type M Magnetic Unibrake Motors. For quick, controlled stopping... especially when you want to hold the load. Spring-setting magnetic brakes of the friction disc type combine with motor in a compact, integral unit. Sizes... ⅛ to 150 H.P.

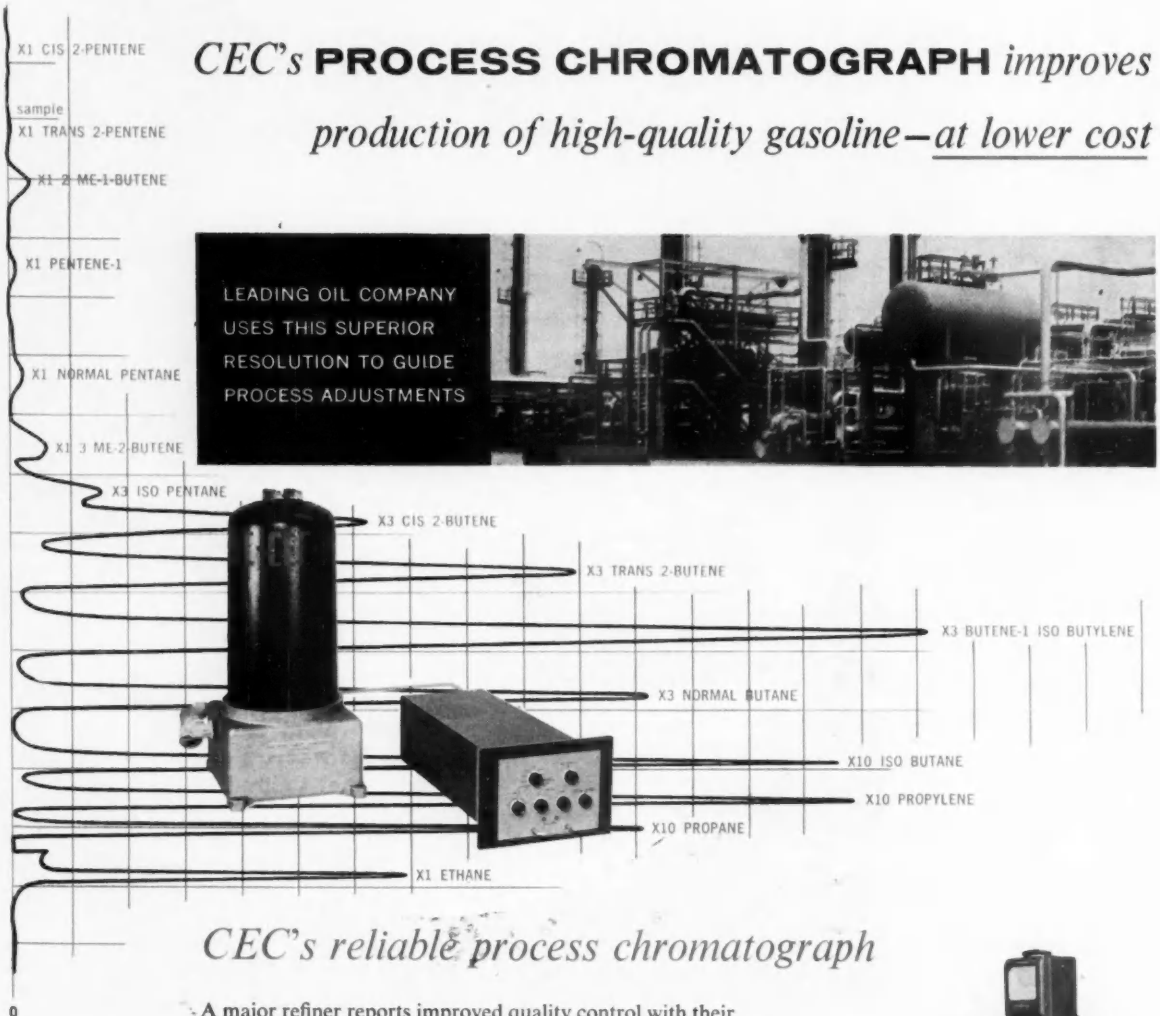
MASTER GEARMOTORS and variable speed drives can be furnished with Unibrakes, too. See Master for the perfect power drive for you.

THE MASTER ELECTRIC CO.

DAYTON 1, OHIO

DIVISION OF RELIANCE ELECTRIC AND ENGINEERING CO.

CEC's **PROCESS CHROMATOGRAPH** *improves production of high-quality gasoline—at lower cost*



LEADING OIL COMPANY USES THIS SUPERIOR RESOLUTION TO GUIDE PROCESS ADJUSTMENTS

CEC's reliable process chromatograph

A major refiner reports improved quality control with their CEC 26-202 Chromatograph which is used in continuous monitoring of a depropanizer column. Rapid instrument response takes the guesswork out of process adjustment, helps produce higher-quality gasoline at lower costs.

For automatic, continuous remote-control monitoring and for the recording of multiple streams, no instrument can surpass the 26-202's simplicity, precise reproducibility, and precise regulation.

Sample volumes are reproducible to better than ± 0.5%, temperatures are controlled to less than 1°F.

This completely transistorized system provides *trouble-free, continuous service.* The Analyzer unit meets specifications for installation in Class I, Group D, Division 1 hazardous locations. The Control unit can be located at least 500 feet from the Analyzer. *Contact your nearest CEC Field Office or write for Bulletin CEC 1836-X26.*

. . . and for the laboratory

CEC's versatile 26-201A Laboratory Chromatograph guarantees speed and superior reproducibility. Easily operated by untrained help, the 26-201A features an exclusive Thermostatted Pre-Cut Column which reduces complex analysis time to minutes. Other exclusives are a capillary high-pressure sampling accessory and a heated sample vaporizer which assures reproducibility of better than ± 0.5% with sensitivity in parts-per-million. *Contact your CEC Field Office, or write for Bulletin CEC 1831A-X8.*

NO MATTER WHAT YOUR PROBLEMS ARE

Simply state your needs. CEC's Application and System Engineers are available to design and install complete systems for any application. *Contact your CEC Field Office.*

Analytical & Control Instrument Division

Consolidated Electrodynamics

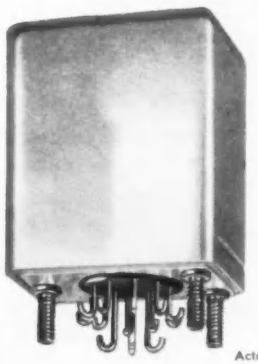
300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

NEW

RBM

BHSM and BHSM HT TYPES



Actual Size

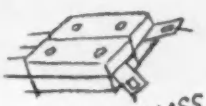
Miniature Hermetically Sealed Relays

The reliability of this relay under severe conditions of vibration and shock has been field-proven in many applications. It is another example of how R-B-M's production maturity and complete facilities can eliminate many of your engineering problems.

WITHSTANDS 10g – 500 CYCLE VIBRATION

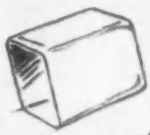
"RUGGEDIZED" WELDED RELAY AND BRACKET ASSEMBLY

DEPENDABLE X-BAR CONTACTS



SILICONE-GLASS PILE UP INSULATORS (HT VERSION)

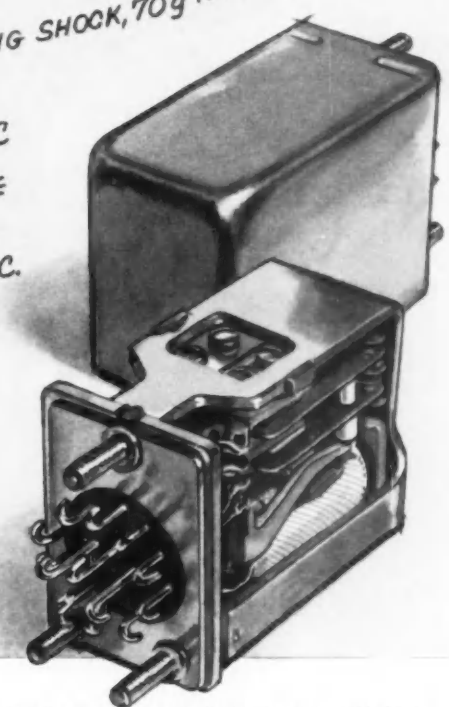
KEL-F COIL BOBBIN AND TEFLON MAGNET WIRE (HT VERSION)



HERMETICALLY SEALED OR DUST COVER AVAILABLE

OPERATING BENEFITS

- 125°C OPERATING AMBIENT
- TEMP. RANGE } 22700 BHSM TYPE, -55° TO +85°C; 22800 BHSM HT TYPE, -65° TO +125°C
- COIL UP TO 130 V.D.C. } SENSITIVITY 0.2 W. MIN. PER POLE; MAX. COIL DISSIPATION 3.75 W.
- CONTACTS – MAX. 4PDT 3 AMP. AT 32 V.D.C. OR 115 V.A.C. (NON-INDUCTIVE)
- SPECIAL CONTACTS AVAILABLE FOR LOW LEVEL OR DRY CIRCUIT APPLICATIONS
- APPROX. WEIGHT – 3.25 OZ.
- 30g OPERATING SHOCK, 70g NON-DESTRUCTIVE



Consult your local RBM Product Application Engineer or write for Bulletin BHSM-1.

RBM Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

New!

Brush

Mark II

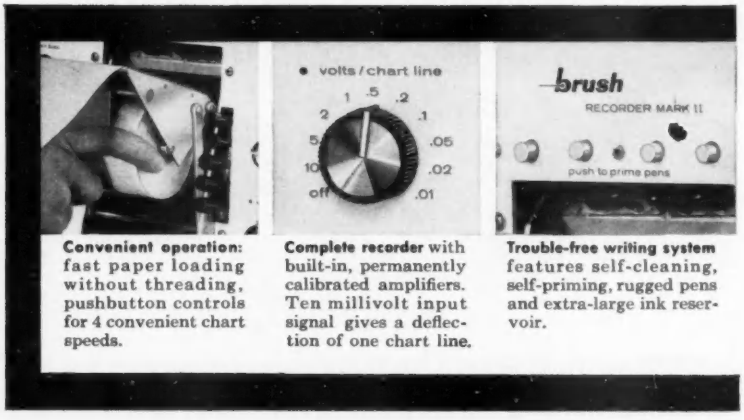
plug it in . . . put it in writing . . . anywhere!

Recording with the new Brush Mark II is remarkably simple.

Operation is foolproof, with push-button chart speed selection . . . fast paper loading . . . self-cleaning, self-priming pens... built-in, permanently calibrated amplifiers.

Recordings are accurate . . . easy to interpret . . . easy to reproduce. Mark II operates over a wide amplitude and frequency range (d.c. to 100 cps), provides high stability, extreme sensitivity with an input range of 10 millivolts to 400 volts.

See how Mark II can speed your work, help you obtain data — the Brush way.



Convenient operation: fast paper loading without threading, pushbutton controls for 4 convenient chart speeds.

Complete recorder with built-in, permanently calibrated amplifiers. Ten millivolt input signal gives a deflection of one chart line.

Trouble-free writing system features self-cleaning, self-priming, rugged pens and extra-large ink reservoir.

brush INSTRUMENTS

DIVISION OF CLEVITE CORPORATION

3405 PERKINS AVENUE CLEVELAND 14, OHIO

IT'S NEW!...IT'S FASTER!
IT'S MORE ACCURATE!

ELECTRONIC DIGITAL VOLTMETER — EDVM

Noiseless — Transistorized — No Stepping Switches. Identifies point in problem being read. Read-out in .005 seconds. Accuracy of 0.01%. Moving parts replaced by solid state circuits.

AUTOMATIC DIGITAL INPUT-OUTPUT SYSTEM — ADIOS

Servo-set attenuators, pre-programmed on punched paper tape, permit four times faster pot setting. Two seconds per set with 0.01% accuracy.

PATCH-BOARD CLUTTER ELIMINATED

Countless studies at EAI Computation Centers dictated modular concept adopted in new, oversize Patch Panel design. Logical grouping of component connections replaces long patch cords with compact bottle plugs. "Hold" and "Reset" control now provided for individual amplifiers. Connections for 3,450 terminations facilitate maximum future expansion.

AUTOMATIC EXTENDED READ-OUT — AERO

Problem read-out points selected by Push Button Control. Read-out Time — Instantaneous on EAI's new EDVM. Print-out — Four readings per second on new EAI Printer.

The 231-R Computer provides more computing at less cost, in less space than ever before achieved in analog computer design. For complete details, contact Electronic Associates, Inc., Long Branch, New Jersey, Dept. CE-4.

ELECTRONIC ASSOCIATES Incorporated • • • • • MANUFACTURERS OF PACE PRECISION ANALOG COMPUTING EQUIPMENT

LONG BRANCH, NEW JERSEY • TEL. CAPITOL 9-1100

Making the Most Out of Maintenance

The growing complexity of control equipment is hitting users hard in the maintenance department. You hear concern about maintenance of control from all sides: the military, the process industries, and the metalworking shops.

Cost is high

A recent statement by a military man (CtE, Feb., p. 40) points out how big the problem is getting. This speaker claimed that military maintenance costs ran ten times the initial investment in gear; that military maintenance was costing up to $20 million per day.

Other military maintenance specialists tell you that the "ten times" figure is probably high; it might apply in a few special cases, such as the maintenance on a computer-controlled airplane. More in line, they say, is a report by the U.S. Army's Signal Corps, which figures it spends one-third the initial cost of its Missile Master system—a complex control system for firing missiles—for maintenance each year.

The armed services have probably gathered the most data on maintenance. Specialists see three serious difficulties that hurt industrial users as well as military men. The problems: personnel, troubleshooting, and spare parts.

The maintenance man

To repair today's complicated control equipment, the maintenance man has got to have above average intelligence. Experts agree that if you are starting from scratch to train electronic repairmen it's best to teach them basic circuits and how basic components work. The repair man can learn the system on the job. And if the system should change, he won't find it too difficult, with his background, to learn the new system.

One refinery solved its maintenance personnel problem this way. Before its first electronic control system was installed, the refinery hired men with electronic experience (radio, TV, or military) who had never been inside a petroleum plant before. Then, when the system was installed, the new men were assigned to work with the control manufacturer.

The Signal Corps figures that, starting from scratch, it takes about 30 weeks of training courses, followed by three to six months of field work, to turn out a skilled electronics technician.

Troubleshooting

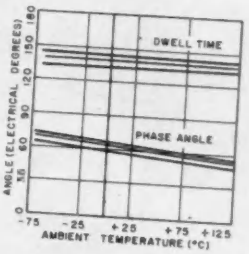
Troubleshooting eats up the bulk of the repair man's time. The Signal Corps has found that, on the average, its mainte-

Chopper Characteristics for Every Use

Center Pivoted for Shock Resistance

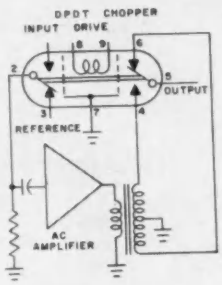
Here is a chopper that operates during shock and vibration. The moving armature of Airpax Series 350 chopper pivots at its center of gyration. This construction prevents external forces from affecting the chopper's operation—gives you performance where other choppers fail.

High Temperature for Remote Location



Volatile materials are avoided in Airpax choppers. Operation to +100C is standard for most types. Airpax Series 310 chopper operates to +125C. Units for higher temperatures are also available.

Double-Pole Double-Throw for Synchronism

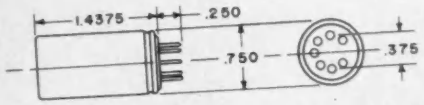


For close tracking between two sets of chopper contacts, Airpax manufactures DPDT choppers. The two sets of contacts track within 5 degrees. Airpax also supplies choppers in matched pairs for modulator-demodulator applications.

AIRPAX
DESIGNERS ENGINEERS

Airpax Products Company, Cambridge Division
Jacktown Road, Cambridge [illegible]d

Hermetically Sealed for Long Life



Airpax continues to lead the way with hermetically sealed choppers. A chopper that can be opened for adjustment usually comes to need adjustment. A chopper that is permanently adjusted and sealed in the air-conditioned Airpax factory is safe from contamination for life.

nance people spend 60 min troubleshooting for every 20 min repairing equipment.

One of the reasons, some specialists feel, is that operating and maintenance manuals have been written by and for engineers —not maintenance men. They urge that these books be written in the maintenance man's language, pinpointing maintenance and repair instructions and making them easy to find.

Piece part problem

Troubleshooting time has been shortened by increasing modularization. Said one maintenance man, "The piece-part problem was killing us. Now we have 10 or 12 components molded together in a plug-in unit." Mounting a complete circuit on a card is also winning favor. Troubleshooting attempts to identify the circuit that is causing the difficulty. When it's located, a new card is taken from a file of spares and inserted, and the damaged one repaired or returned to the manufacturer for repair.

But what maintenance men are looking for is some easy formula, like the procedure at one installation: First, check all connections; second, check the tubes!

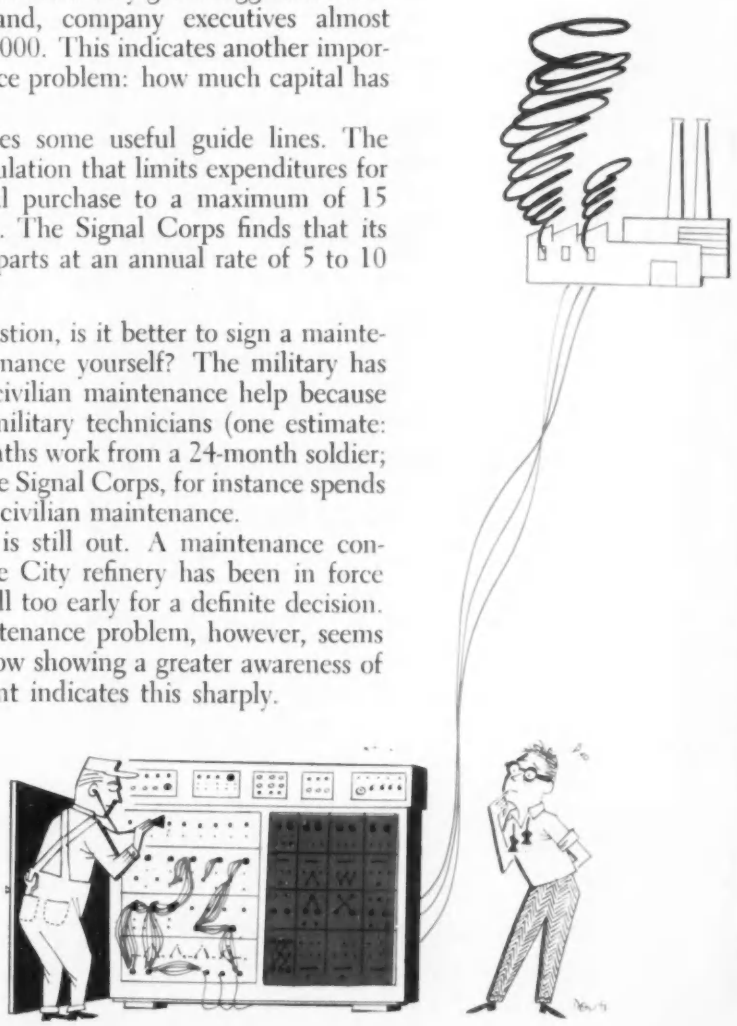
That leads to the last problem—spare parts. Recently a refinery installed an electronic data logger. The company was pleased with the price of $60,000. But when they got a suggested list of spare parts to keep on hand, company executives almost exploded; the list totaled $20,000. This indicates another important aspect of the maintenance problem: how much capital has to be tied up in spare parts?

Again the military supplies some useful guide lines. The Army, for example, has a regulation that limits expenditures for spare parts at time of initial purchase to a maximum of 15 percent of initial investment. The Signal Corps finds that its complicated gear uses spare parts at an annual rate of 5 to 10 percent of initial cost.

Still unanswered is the question, is it better to sign a maintenance contract or do maintenance yourself? The military has been forced to buy outside civilian maintenance help because of its constant turnover of military technicians (one estimate: the services get only nine months work from a 24-month soldier; the rest goes for training). The Signal Corps, for instance spends almost $5½ million a year for civilian maintenance.

But for industry the jury is still out. A maintenance contract at Tidewater's Delaware City refinery has been in force for almost 18 months. It's still too early for a definite decision.

One thing about the maintenance problem, however, seems sure. Design engineers are now showing a greater awareness of the problem; newer equipment indicates this sharply.



PHILCO

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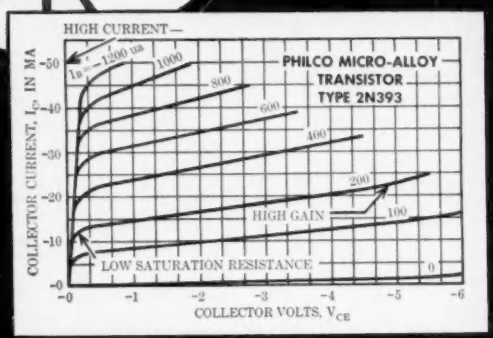

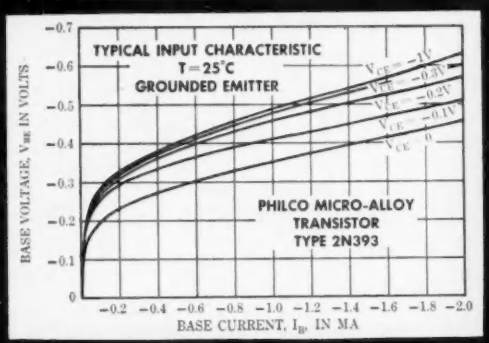

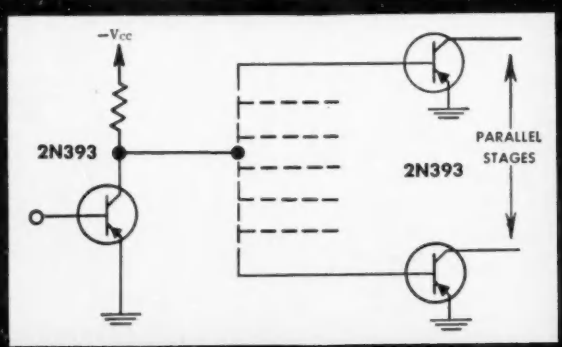

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Control ENGINEERING

APRIL 1958

* Copies of the report, entitled "America's Top Management Suggests Improved Methods of Communication Between Research Laboratories and Executive Offices", are available from the Scientific Apparatus Makers Association, 20 North Wacker Drive, Chicago 6, Ill.

Talk to businessmen in their language

While your primary job is design and application, clear interpretation and evaluation of your accomplishments is a responsibility that is critically important to you and to your management. Perhaps the responsibility of reporting in business, rather than purely technical, terms has never been clearly delegated to you. Nevertheless, top executives expect it of you, as a study* by the Scientific Apparatus Makers Association indicates. The study also quotes suggestions by America's top executives on how you can improve your reporting. The statement of one describes what you should do: "Clearly indicate the status of the work, the advantages and disadvantages of pursuing the work further toward production, the financial implications of the adoption of a new development for production (plant obsolescence, new investment in plant, tooling costs, etc.), and the situation relative to competitive companies." Another tells what you should not do: "Merely recite steps taken and difficulties encountered without furnishing an appropriate evaluation of progress against planned progress". Intended originally for research and development people, the advice applies so well to design and application engineers that we feel compelled to draw it to your attention now.

How to heed this advice? Separate, from the final analysis, descriptions of all preliminary work, testing procedures, and proof of results. Project the analysis into dollar advantages, if they exist, for the company and its customers (marketing people will probably help you with this projection). Report frequently. Communicate significant results in person—the study indicates that this is the procedure in nine out of ten satisfactory cases. Use seminar-type presentations with scale models and other props. Fit them to the backgrounds and interests of your management.

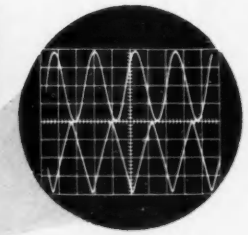
Management can do a lot to pave the way for you. Executives who participated in the study admit that they need more frequent and more personal contact with their technical personnel, more technical study groups to dissolve the communication barrier. One who has recognized the difficulty in his company says, "In our organization there has been a trend toward separation of management from the working research man; we are working now to reverse this trend." Help by speaking to the ear that understands what and why.

THE EDITORS

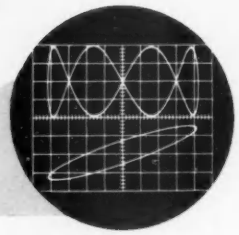
NEW DUAL-BEAM OSCILLOSCOPE

Tektronix Type 502

- TWO-GUN CATHODE-RAY TUBE.
- 200 μv/cm SENSITIVITY, BOTH BEAMS.
- DIFFERENTIAL INPUT, ALL SENSITIVITIES.
- 2, 5, 10, and 20 TIMES SWEEP MAGNIFICATION.
- CURVE TRACING with TWO BEAMS—(horizontal input sensitivity to 0.1 v/cm).
- SINGLE-BEAM CURVE TRACING at 200 μv/cm, BOTH AXES.
- EXTRA FEATURE—Both amplifiers have transistor-regulated parallel heater supply.



Dual display on linear time base.



Dual display for X-Y curves.

Here are a few uses for the Type 502:

IN ELECTRONICS—Use the Type 502 as a general-purpose oscilloscope and also to show simultaneously the waveforms at any two points in a circuit, e.g. input and output, opposite sides of a push-pull circuit, trigger and triggered waveform, etc.

IN MECHANICS—Display, compare, and measure outputs of two transducers on the same time base; plot one transducer output against another—pressure against volume or temperature for instance; measure phase angles, frequency differences, etc.

IN MEDICINE—Display, compare, and measure stimulus and reaction, or the outputs of two probes, on the same time base; use differential input to cancel out common-mode signals, or to eliminate the need for a common terminal; use in routine investigations, etc.

IN ALL FIELDS—The Type 502 can save you more than its cost in time—in as little as one application!

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HIGH-GAIN AMPLIFIERS

200-microvolts/cm deflection factors, both dc-coupled and ac-coupled. 16 calibrated steps from 200 μv/cm to 20 v/cm.

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Differential Input, Both Channels—Rejection ratios: 1000-to-1 at 1 mv/cm or less, 100-to-1 at 0.2 v/cm, 50-to-1 at 5 to 20 v/cm.

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WIDE-RANGE SWEEP CIRCUIT (Common to both beams)

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Sweep Magnification—2, 5, 10, and 20 times, accurate within the maximum calibrated sweep rate.

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Regular shipments of the Type 502 are expected to begin during June, 1958. However, your Tektronix Field Engineer or Representative quite likely will be able to arrange a demonstration somewhat sooner. Please keep in touch with him for current details. If you don't know where to find him, a postcard to the factory will get you that information along with complete specifications on the Type 502.

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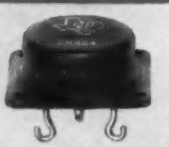
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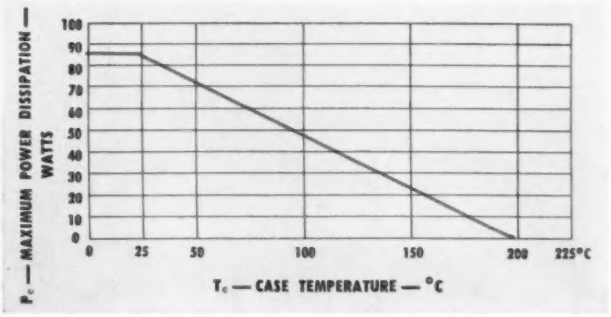
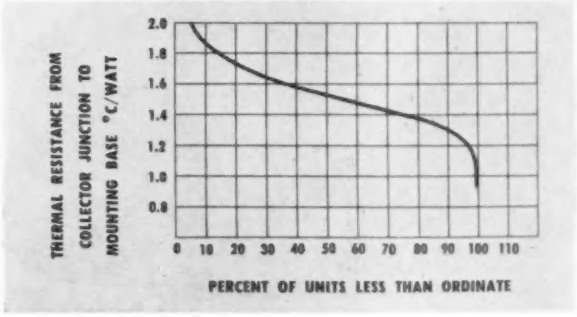
45 WATTS at 100°C . . . OPERATION TO 200°C





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Both units are derated from 85 watts at 25°C to 200°C and combine the additional advantages of low distortion . . . stability . . . high reliability.

		2N389		2N424		
	Test Conditions	min	max	min	max	units
BV_{CEX}	I_C = 10mA, R_{EB} = 33 ohms	60	—	80	—	volts
BV_{EBO}	I_B = 10 mA	−10	—	−10	—	volts
R_{CS}	I_C = 1A, I_B = .2A	—	5	—	10	ohms
V_{BE}	V_{CE} = 10V, I_C = 1.5A	—	8	—	—	volts
V_{BE}	V_{CE} = 10V, I_C = .75A	—	—	—	8	volts
h_{FE}	I_C = 1A, V_{CE} = 10V	10	60	—	—	
h_{FE}	I_C = 1A, V_{CE} = 15V	—	—	10	60	
P_C	T_C = 25°C	—	85	—	85	watts
P_C	T_C = 100°C	—	45	—	45	watts
	Storage Temperature	−65°C to +200°C				

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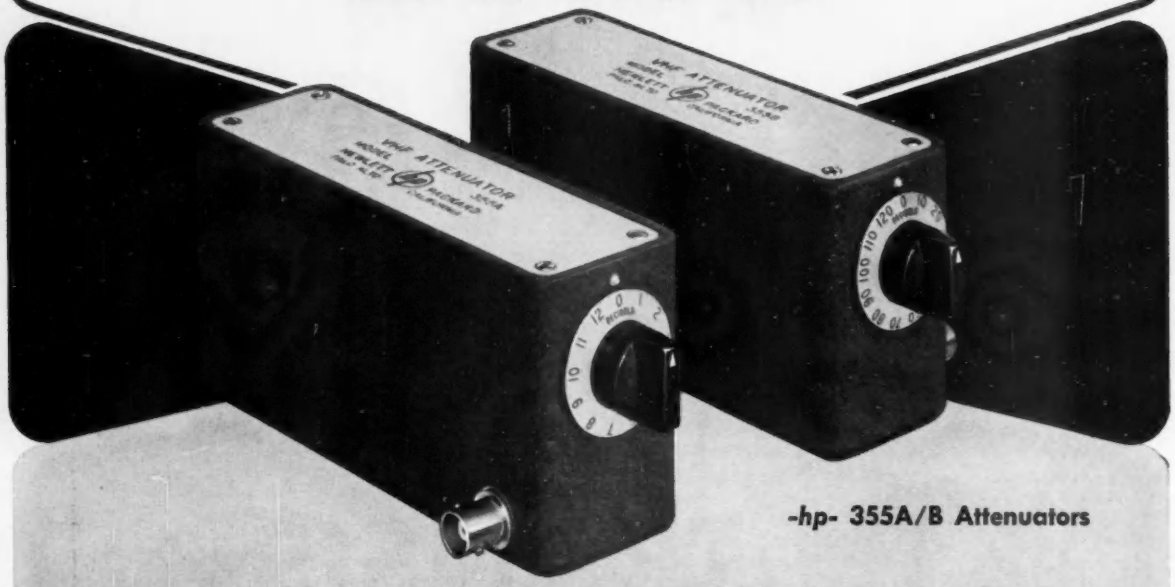
0 to 132 db in 1 db steps— DC to 500 MC



-*hp*- 355A/B Attenuators

¼ db accuracy full range for low attenuation values. Maximum error at full attenuation 2 db. "One-knob" control. Super compact design—size approximately 2½" x 2½" x 6".

These are characteristics of the new, rugged, simple -*hp*- 355A/B attenuators.

-*hp*- 355A provides 0 to 12 db in 1 db steps. -*hp*- 355B provides 0 to 120 db in decade steps. Together, 132 db of attenuation from DC to 500 MC is available, with simplest possible controls, premium accuracy, and no complex setup. A solid-shield 50 ohm connector may be used to interconnect the two attenuators.

These new -*hp*- attenuators have balanced capacities and completely shielded sections. They are enclosed in a sturdy metal case, yet weigh only 1½ pounds.

Ask your -*hp*- representative to show you these practical, minimum-space attenuators this week.

SPECIFICATIONS

Attenuation: -*hp*- 355A, 12 db in 1 db steps. -*hp*- 355B, 120 db in 10 db steps

Frequency Range: DC to 500 MC

Overall Accuracy: -*hp*- 355A, ±0.25 db, DC to 500 MC. -*hp*- 355B, ±1 db, DC to 250 MC, ±2 db, 250 to 500 MC

Nominal Impedance: 50 ohms

Maximum SWR: 1.2 to 250 MC, 1.5 to 500 MC

Max. Insertion Loss: 0 at DC, 0.4 db at 60 MC, 1 db at 250 MC, 1.5 db at 500 MC

Power Dissipation: 0.5 watt average; 350 v peak

Connectors: BNC

Size: 2-3/16" wide, 2-5/8" high, 6" long. Net weight 1½ pounds

Price: -*hp*- 355A, $125.00. -*hp*- 355B, $125.00

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Punched-Tape Positioning Controls Britain's Newest Wind Tunnel

In Britain's new 8-ft continuous flow windtunnel, covering speeds up to Mach 2.8, punched-tape positioning systems create the working section by flexing two 62-ft-long, 1-in.-thick steel plates to an accuracy of plus or minus 0.005 in. and operate the equally large diffuser section.

Speed control of the 80,000-hp compressor—the largest in Europe—has to be maintained to within 0.1 percent. To provide flexibility three modes of operation are available. In this article by Control Engineering's European Editor, these systems, together with the system for moving a 1½-ton aircraft model, are described.

DEREK BARLOW, Control Engineering, London

In subsonic and supersonic wind tunnels of the continuous flow type, two variables—air flow and compressor speed—must be accurately determined and controlled. In subsonic runs, the air flow is controlled by varying the compressor speed, while supersonic speeds are developed and regulated by a suitably shaped nozzle introduced at the working section. To slow the airstream down to subsonic speeds for re-entry to the compressor, a diffuser section of the same physical dimensions is required downstream of the model.

In Britain's newest 8-ft tunnel—one of the largest of its kinds in the world—infinitely variable nozzle shapes for different Mach speeds are formed by flexing steel plates at the top and bottom of the working section. These plates are contoured by tape-controlled hydraulic operated screw jacks, Figure 1. Over a range of Mach speeds from 1 to 2.8 in increments of 0.01, a single knob control automatically positions the flexible plates and the diffuser panels in accordance with the punched tape program, while the tunnel is on stream.

The tunnel, recently constructed at the Royal Aircraft Establishment, Bedford, is an 820-ft closed-circuit structure in which the compressor is an integral part. The working section operates over a range of from 0.1 to 4 atmospheres absolute.

Nozzle and diffuser system

The flexible plates forming the top and bottom of the working section are each 62 ft long, 8 ft wide, and 1 in. thick, and are supported on 30 pairs of 30-ton mechanical jacks. Each pair of jacks, comprising a jacking station, is driven by a 5-hp hydraulic rotary motor.

To provide shockfree, uniform airflow past the model at high Mach speeds, the plates must be accurately curved to within 0.005 in. between each jacking station. This requires precise control of each station throughout the speed range of the tunnel, and freedom of movement when the tunnel is sealed and the compressors running. Accuracy of control of the diffuser panels, not so critical, requires a positional accuracy of only 0.050 in. The design thus takes the form of a series of movable panels situated in the side walls of the tunnel downstream from the working section, with adjustable air inlet doors providing a by-pass circuit to prevent compressor stalling. A tape-controlled impulsing system actuating an on/off hydraulic servo loop provides the single knob control required for setting the flexible plates and the diffuser panels, Figure 2.

Each jacking station is controlled by two identical punched tapes, one for positioning and one for monitoring. Reversible tape readers move in synchronism, controlled by the impulses provided from a central 6.5-per-second pulsator, and the number and polarity of the impulses is dependent on the Mach speed control setting.

The tape readers employ standard five-channel tape. Each tape perforation corresponds to a jack movement of 0.0025 in. except in the downstream area where more accuracy is required. Here, by changing the jack lead screw, 0.00125-in. steps are obtained. With a maximum jack movement of 34 in. from Mach 1 to 2.8 the 14,000 perforations

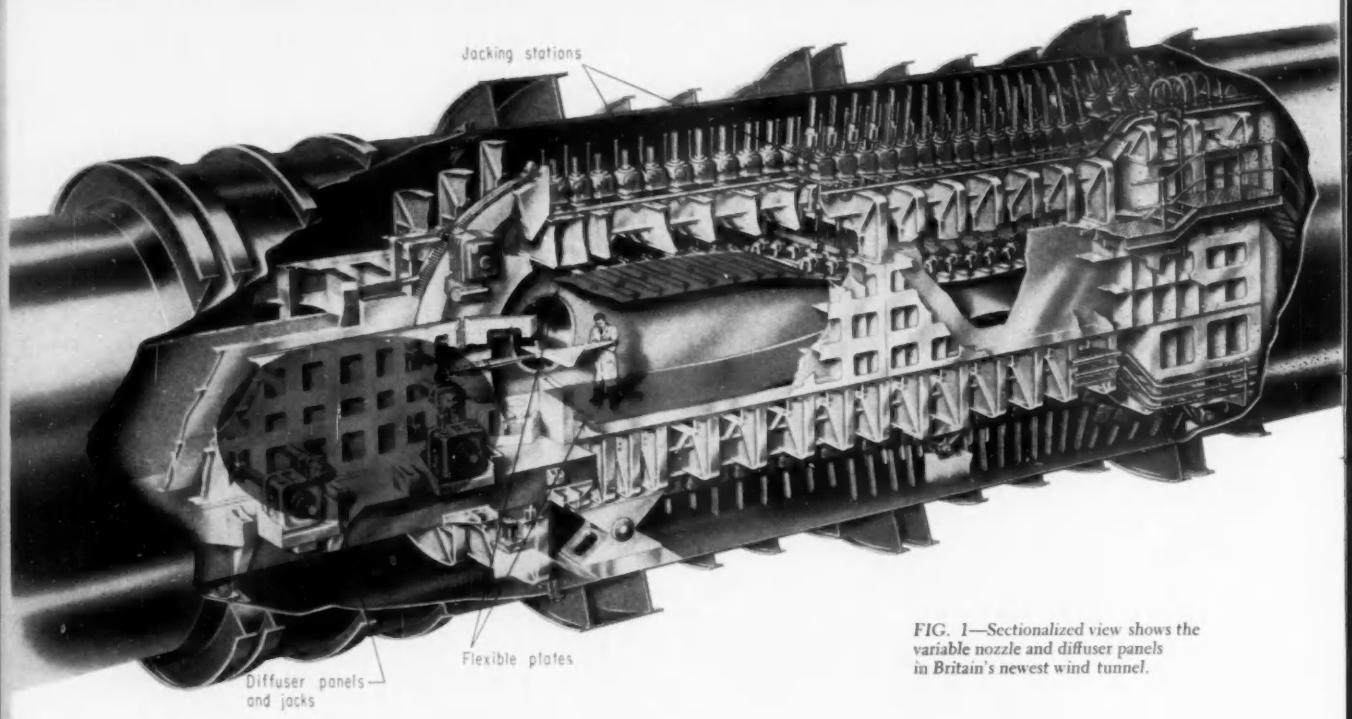


FIG. 1—Sectionalized view shows the variable nozzle and diffuser panels in Britain's newest wind tunnel.

required make tape lengths of 125 ft necessary on each of the 30 tape readers. The number and spacing of the perforations are so arranged that with the tapes starting from a common datum at Mach 1, the nozzle would successively pass through all the correct profiles up to Mach 2.8 in 40 min. When airspeeds must be lowered, the tape direction is merely reversed.

Of the five channels, the two outer rows of perforations control the upper and lower stations individually, since their movements may need to be slightly different to achieve uniform air flow. The two inner rows provide reversing signals for the upper and lower stations, and the center row, used on only eight tapes, controls the diffuser throat. On receipt of the impulse from the signal tape, Figure 3, the correct single revolution clutch (one of a pair to provide directional information) is energized and connected through a differential to a constant speed ac motor. The clutch in its one revolution advances a geared nut through a given angular displacement on an accurate pilot leadscrew attached to the flexible plate between the plate stiffener and main jack thrust beam. The nut displacement opens, through mechanical linkage, a specially designed hydraulic pilot valve sensitive to movements of 0.0005 in. Opening the pilot valve allows the main directional hydraulic valve to admit oil at 665 psi to the 5-hp jack motor, which advances the jacks 0.0025 in. or 0.00125 in., according to the leadscrew pitch. The packs and lead nuts move in opposite directions, thereby restoring the pilot valve to the closed position, the original nut displacement acting as the error signal.

Checking contacts on the pilot-nut drive are constantly aligned with identical checking contacts on the monitor units, the latter being driven by impulses from the monitor tape. Should misalignment occur between the two contact banks, the whole system is automatically stopped. In this way inappropriate nozzle profiles and/or plate stresses due to misreading of the positioning tape are avoided.

Manually generated impulses, to take up discrepancies and adjust the airflow characteristics, can be injected in either direction to any of the 30 jacking stations; indicators show the number of steps injected.

To prevent plate-overstress during flexing, curvature gages, each consisting of a differential transformer with an actuating stylus so mounted that its movement gives continuous indication of the stresses in the plates, are fitted at each jacking station. Overstress due to a shrinking radius of curvature causes the wall movements to be halted. On any change of Mach number, an automatic scanner checks each gage for stresses outside predetermined limits.

A similar system, Figure 4, controls the side panels of the diffuser section actuated from the center row of the working section control tapes. The five side-wall hinged sections (the longest is 25 ft, the shortest is 5 ft) are moved by hydraulic screw jacks. A servo system replaces the impulse units used on the flexible plates. Each tape step provides a wall movement of 0.050 in. with a maximum rate of 1.8 in. per minute and positioning accuracy of 0.050 in. Manual corrections can be

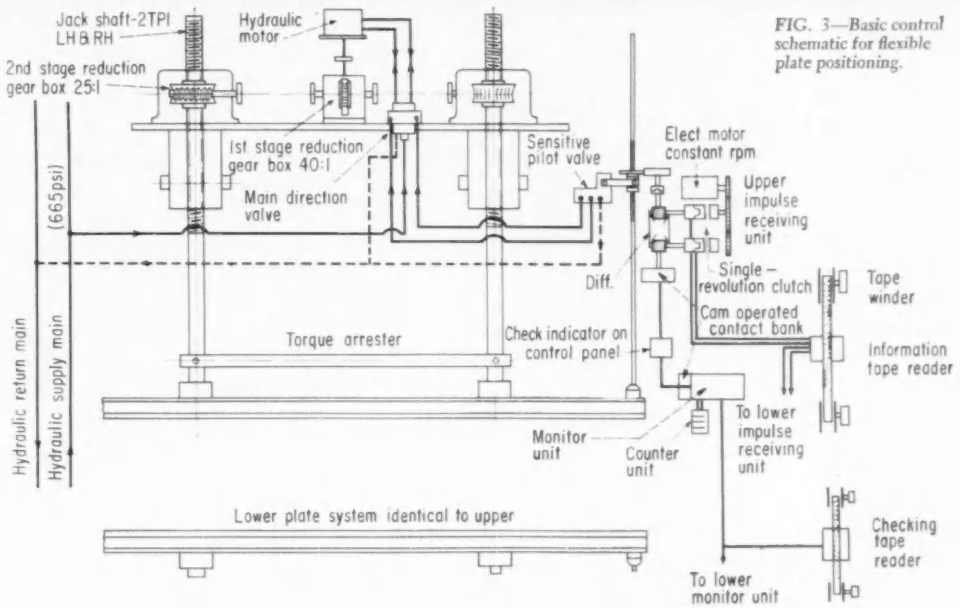


FIG. 3—Basic control schematic for flexible plate positioning.

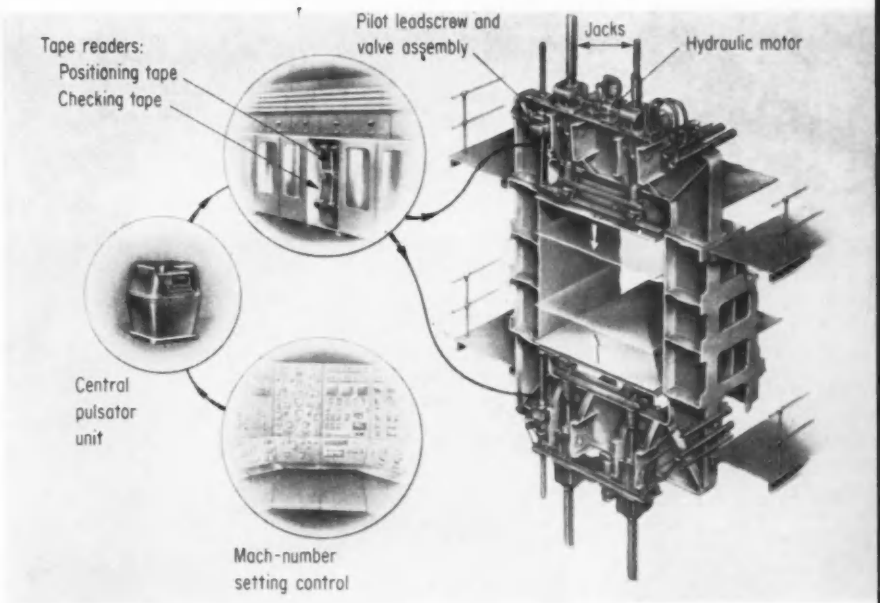
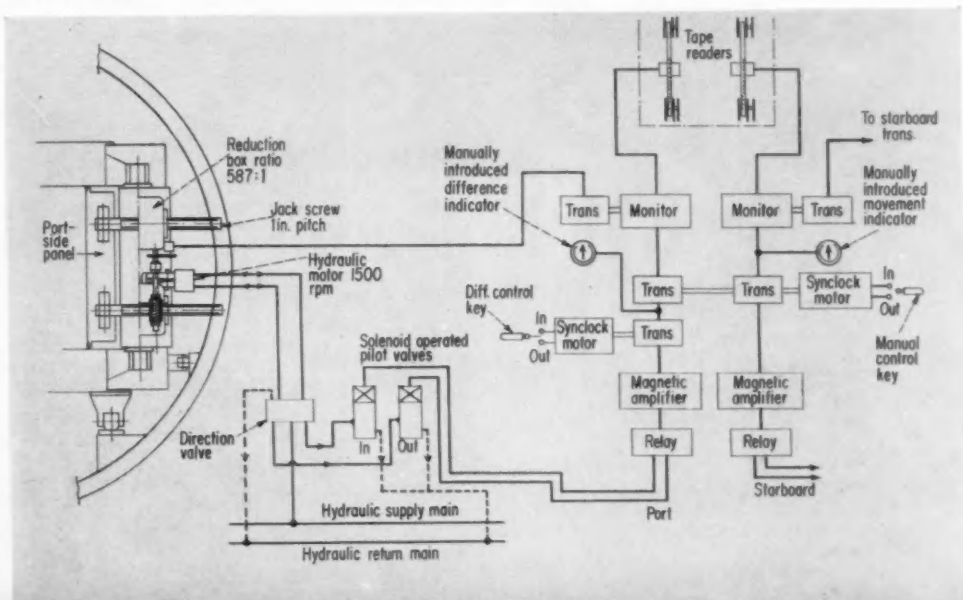


FIG. 2—Control components involved for each jacking station.

FIG. 4—Diffuser section control schematic.



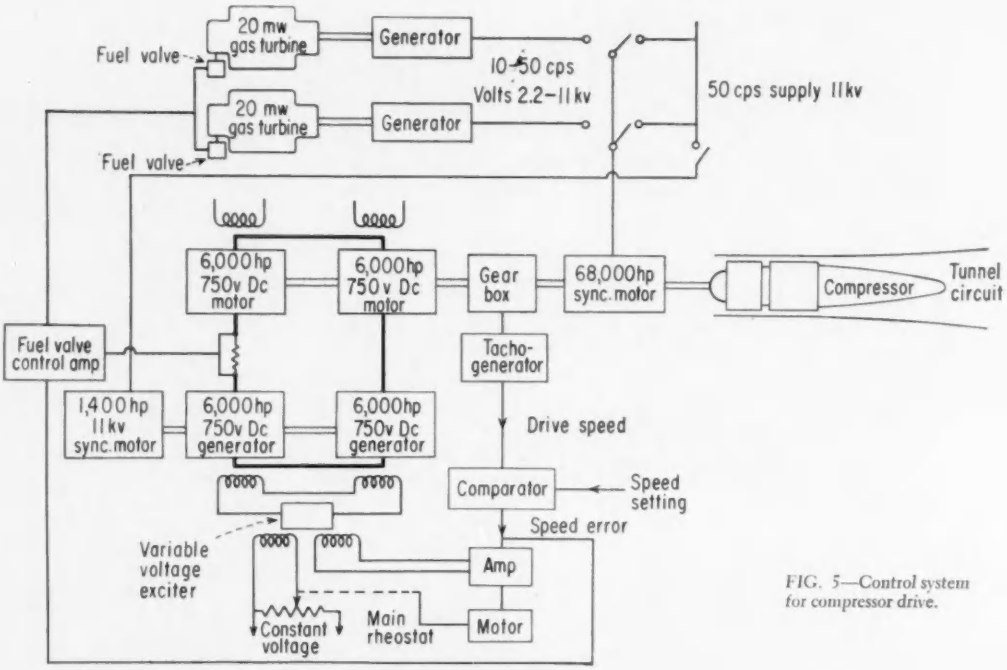
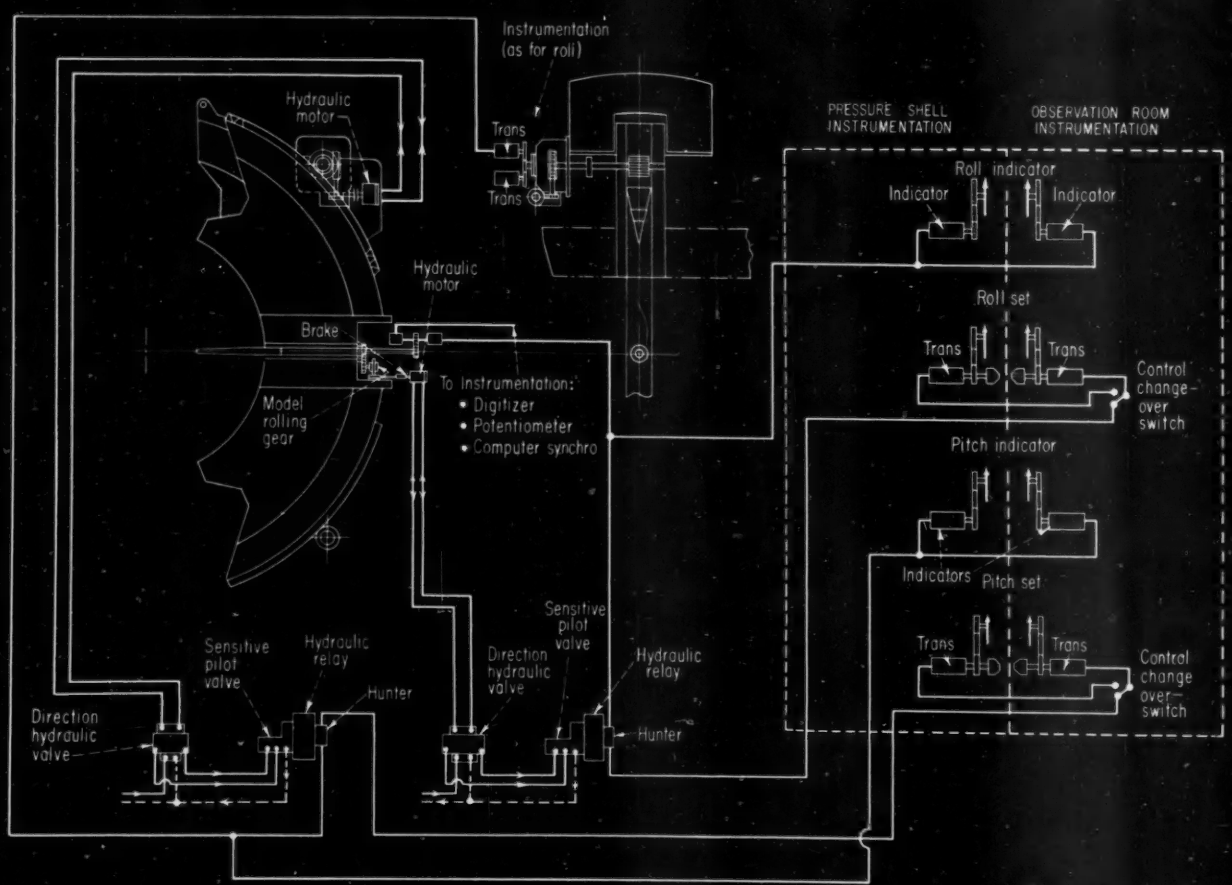


FIG. 5—Control system for compressor drive.

FIG. 6—Control schematic for model roll and pitch.



made on any of the panel positions, either in port and starboard pairs or individually to achieve optimum airflow.

Compressor control system

The main compressor, the largest in Europe, is a ten-stage axial machine driven by a 68,000-hp, eight-pole synchronous motor connected through a gearbox to two 6,000-hp dc pony motors operating in tandem. These two dc motors are energized in a simple series loop Ward-Leonard system by two similar machines acting as generators and driven by a 14,000-hp, 11-kv, 10-pole synchronous motor with automatic sequence control reactor starting, Figure 5.

Three modes of operation of the compressor are possible:

1. For subsonic work on reduced loads the compressor can be driven by the 12,000-hp dc motors alone, with the 68,000-hp machine disconnected, providing a range of 150/750 rpm.
2. For high power the 68,000-hp motor can be run at a fixed speed of 750 rpm, drawing its supply from the national grid system, with the dc motors contributing a further 12,000 hp.
3. For full power variable speed, the main 68,000-hp motor is driven from a variable frequency supply of 10-50 cps, generated by two 20-mw gas turbine generating sets. These provide a variable voltage of 2.2-11 kv over the frequency range.

Efficient operation of the tunnel at subsonic and supersonic speeds demands accurate compressor speed control. The automatic speed control system, with an accuracy of 0.1 percent of the set speed, obtains its speed setting signal from a spirally wound potentiometer whose dc source is stabilized. The compressor control signal is derived from the rectified output of an inductor-type, temperature-controlled tachogenerator driven from the main gear box.

The error signal originating from the comparison of the set speed and the tachometer signal operates two control systems, one for rapid response covering speed disturbances up to 10 percent of the set speed and the other for wider speed changes.

In the rapid response system, control is exercised by voltage variation on an auxiliary field of the variable voltage exciter supplying the two 6,000-hp dc generators in the Ward-Leonard set.

Wider speed variations outside the range of the rapid response system control operate a power rheostat in the main field circuit of the same variable voltage exciter which sets the coarse speed.

When the main 68,000-hp motor is being driven from the variable frequency gas turbine source, the error signal controls the gas turbine fuel valves through a servo link to take up major load changes beyond the capacity of the dc machine.

Model control system

Two separate positioning systems provide the pitch and roll settings for the model, which may weigh up to 1½ tons (Figure 6). For pitch position an electrohydraulic system controls the 11-ton pitching quadrant over an arc of 45 deg. A straightforward magslip system transmits the desired settings via directional hydraulic valves to achieve a positional setting accuracy of the quadrant to better than 0.025 deg.

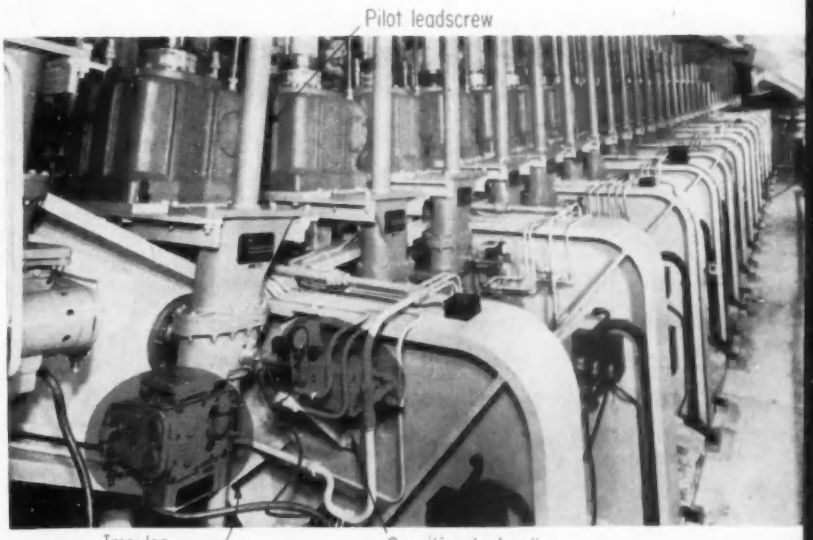


FIG. 7—The jacking stations within the inner shell of the tunnel showing impulse receiving unit and hydraulic valve actuated by the pilot lead nut.

A similar servo system provides roll motion by rotation of the sting (point support) on which the model is mounted, through 180 deg. Housing the drive system within the pitching quadrant—a cross section of only 10 by 30 in.—and achieving a positioning accuracy of 0.125 deg against a torque load of 3 ton-feet necessitated using a small hydraulic motor operating at high speed; this aggravated the accuracy problem. A 1,920:1 gear reduction achieved by a final spur stage and two contra-rotating worm gear systems to eliminate backlash gave an accuracy of 0.125 deg.

A new approach to collecting
Instrument-Industry Statistics

LOUIS A. EDELMAN, U. S. Dept. of Commerce

Here is the first report on how a new philosophy has been applied to handling commodity breakdowns of the instrument industry. The approach: classifying instruments into six major subindustries according to generic product characteristics, then further subdividing into classes based on structural differences. Tested in a survey of optical instruments, the new system of classification made it possible to find optical subassembly sales buried in the Census of Manufactures.

EDITORIAL NOTE:

In the July 1956 issue of CtE, we pointed out the need for a new industry breakdown, one that would assure recognition, definition, and proper classification of the control field. The philosophy described here by Mr. Edelman, and developed by Nathan Golden's division in the Dept. of Commerce, appears to meet these requirements admirably. And it was devised with the instrument and control industry in mind. There is still a serious deficiency, however. At present there's no plan for any followup of this development on an annual or even less frequent basis. The Bureau of the Census is not in a position to replace SIC (the Standard Industrial Classification System) with these new classifications in its Census of Manufactures every five years; and Golden's division has neither the money nor staff to attempt continual surveys of the instrument industry. That would seem to put it squarely up to trade associations, which already collect a variety of data. We suggest that trade associations interested in maintaining instrument statistics get together to find out how this new system of classification can best be used to help serve the members of the industry.—The Editors

The table opposite unveils a major philosophic change in the collection of usable statistics for the instrument industry. It contrasts data gathered using a new generic concept of classification with that available from the 1954 Census of Manufactures, which was based on the Standard Industrial Classification System. Applied to optical instruments and components, this new system divides sales of optical instruments and subassemblies into 14 distinct categories, locates important optical subassemblies lost in the Census figures. The next step is to apply the same philosophy to obtain data on gyro, electrical, and mechanical instruments.

SIC's purpose and limitations

It's been increasingly apparent that the SIC system used by the Dept. of Commerce's Bureau of the Census doesn't supply the instrument industry with all the statistical information it would like to have. The foreword to the SIC manual points out that this system was developed to aid economic analysis. The criterion for industry classification: "To be recognized as an industry, each group of establishments must have significance from the standpoint of the number of establishments, number of wage earners, volume of business, employment and payroll fluctuations, and other features."

One of the major uses of SIC has been to measure the impact of the growth of industrial automatic control instruments and systems on the structure of the nation's economy. For example, SIC Class 3821—"Instruments for measuring, indicating and controlling physical properties"—is considered by many to be a good index of the trends in process "automation". Similarly, Class 3613—"Instruments for measuring, indicating and controlling electrical characteristics"—is a guide to trends in the use of electrical power (another frequently used economic indicator).

But the SIC is not geared to provide the type of commodity data which is significant to instrument manufacturers and users. A manufacturer of a mechanical instrument wants to know whether he's maintaining his market position relative to other makers of mechanical instruments. At the same

time, he is interested in how deeply electrical instruments capable of performing the same function are cutting into his market. Users are interested in similar comparisons, to enable them to mark trends in technology and to help them justify plans.

Understanding this need, Nathan D. Golden's Scientific, Motion Picture & Photographic Products Div. in the Dept. of Commerce's Business & Defense Services Dept. launched a program to develop a new system for product classification—one to supplement, not replace, SIC. The new classification that resulted arranges the members of the instrument industry into homogeneous production groups —analogous to the concept of "an industry" as applied to the steel, automobile and similar groups.

What is called the "instrument industry" represents a very loose category of over 1,000 establishments, many of which are offshoots of other industries. These companies produce several hundred thousand different cataloged items, most of which are difficult to identify with any particular type of facilities, skills, or processes.

Classification difficulty exists not because of the large variety of instruments but because the instruments are defined only in functional terms. Since it is possible to perform the same functions with a variety of instruments (each of which has different structural and operational characteristics and requires different facilities, processes and skills for its production), and since some instruments, with suitable modification, can be made to perform a variety of functions, there is not sufficient differentiation.

GENERIC BREAKDOWN:

1954 SALES OF OPTICAL INSTRUMENTS	(000 of dollars)
Finished optics, mounted and unmounted (except photographic and projection lenses sold separately)	$9,342.9
Magnifiers and reading glasses, including industrial magnifiers and loupes	740.2
Binoculars, telescopes, rifle sights, field glasses, opera glasses, etc.	10,190.2
Microscopes and accessories, including laboratory, students', toolmakers', traveling, stereoscopic, etc.	9,183.3
Photomicrographic equipment	899.5
Optical quality and process control instruments: comparators, optical gages, polariscopes, refractometers, and similar instruments used for measuring and testing goods in process, and for the examination and inspection of finished and semi-finished parts	3,978.4
Spectrographic and spectrometric instruments, including spectrophotometers, monochrometers, etc.	8,899.5
Metallographic equipment and accessories	437.5
Mapping, navigational, surveying, meteorological and geophysical instruments, including photogrammetric map-reproducing equipment	4,617.8
Ophthalmic instruments, including hand diagnostic and refracting instruments, and other visual training equipment	4,244.4
Medical internal examining instruments: endoscopes, peritoneoscopes, cystoscopes, gastroscopes, etc.	2,257.1
Projection apparatus, including slide projectors, microprojectors, cinema projectors, etc.	52,621.0
Photographic lenses: still, motion picture, and special-purpose cameras, and accessory lenses	49,083.5
Optical instruments of specialized nature, including military optical devices such as bombsights, fire-control instruments, periscopes; and other special-purpose instruments not elsewhere reported.	94,267.5
Total sales of optical instruments for 1954	$250,762.8

CENSUS OF MANUFACTURES:

SIC 3831—OPTICAL INSTRUMENTS AND LENSES—1954	(000 of dollars)
Photographic and projection lenses and prisms for sale separately	$31,178
Field glasses, prismatic and nonprismatic; terrestrial and celestial telescopes	9,741
Microprojectors and photomicrographic equipment	977
Microscopes	6,854
Optical measuring instruments refractometers, colorimeters, spectrometers, spectrographs, spectrophotometers, polariscopes, contour projectors, metallographic equipment, etc.	20,719
Other, not specified optical instruments, lenses, parts and accessories	52,344
Total	$121,813

The result: a twofold discrepancy develops. First, products that are manufactured with different types of facilities, processes and skills are placed in one group. Then, instruments that require the same manufacturing processes, facilities and skills are placed in different groups.

Establishing the new classification

The first step in establishing the new classification system was to "redefine" the overlapping instrument industry into clearly defined "subindustries" with homogeneous production characteristics. This meant grouping together all manufacturing establishments which produce similar products with similar facilities, processes and skills. The method devised by the Dept. of Commerce was to divide instruments according to their generic characteristics. This sets up five instrument "subindustries": 1) optical, 2) gyroscopic, 3) electrical, 4) mechanical, and 5) nuclear radiation.

Investigation showed it was necessary to establish still a sixth group, to include packaged instruments and recorder-controller systems.

This sixth class is the result of a dual interpretation of the word "instrument" within the industry. One connotation is a fundamental mechanism which converts electrical, mechanical, or other forms of energy into linear motion or torque to move a pointer or a pen. When the mechanism is enclosed in a case, together with suitable dial or other ancillary parts, it is sold as a complete instrument and identified as a *basic instrument*.

In addition, instrument also can mean a piece of built-up apparatus which contains one or more basic instruments, along with circuitry or tubing. Identified as *packaged instruments*, these comprise up to 80 percent of purchased parts.

To preclude any ambiguity, the term "packaged instrument" is confined to test and measuring instruments, as distinguished from operational equipment. Typical examples: waveform measuring and/or analyzing equipment, field-strength intensity measuring equipment, and multifunction test gear.

To get a more detailed picture of the overall instrument industry, the major groups were subdivided. This was the second step in establishing the new system. A first subclass reflects distinctive structural features. It can be further subdivided on the basis of dimensional characteristics such as size, precision, sensitivity, etc.

The development of the secondary and tertiary subclasses was oriented towards the type of production records generally maintained by the major groups. If production data is usually recorded in terms of the company's model number, then the categories must be sufficiently descriptive to enable every firm in the group to identify its model.

Each instrument class also reflects the functional application of the specific subgroups.

This, then, completes the picture of the homogeneous production group by establishing the three main features of that group: 1) operational, to describe product characteristics; 2) structural, to cover production facilities, processes, and skills; and 3) dimensional and functional, to define functional application.

A survey of optical instruments production, just completed by the Scientific, Motion Picture & Photographic Products Div., illustrates how this new philosophy can work (see data on page 87). The data has been disseminated over 14 categories. Further subdivision and refining are possible, but Dept. of Commerce drew the line at this point to preclude any possibility of revealing data of any individual manufacturer. In addition to identifying all sales of optical instruments and components, the survey permitted the department to determine the current and mobilization capacity for this group.

It is obvious that the data differs materially from that reported in the 1954 Census of Manufactures for Series MC-38-1.2—"Optical Instruments and Lenses Industry", and Series MC-38-2.3—"Photographic Equipment Industry". This is to be expected since much data on optical instrument sales is buried in such SIC classes as medical instruments, photographic equipment, surveying and drafting instruments, and other groups.

The future depends on industry interest

Development of questionnaires for this type of survey requires an intensive knowledge of the product characteristics, functional applications, types of manufacturing facilities, processes, and skills for each of the six major product groups. Therefore the division relies on members of each homogeneous production group for advice and guidance.

Industry interest is the key to the future of the project. The production group as a whole can get no better classification and production data than the individual members of that group are willing to provide. If the group wants detailed data on types, sizes, and sensitivity classes, each member of the group must be willing 1) to maintain his production records in proper detail, and 2) to supply the data in detail.

When the overall instrument program is completed, it should be possible to provide various types of cross-data to, for example, determine not only how many aircraft instruments, recorder-controller instruments, laboratory instruments, quality control instruments were produced, but how many of each of these instrument groups were electrical, mechanical, gyro, etc. Whether such data will ever be available will depend largely on how strongly industry feels it needs this data and how much time and effort it is willing to give to help the Scientific, Motion Picture & Photographic Products Div. gather the pertinent information.

Graphical Analysis of Hydraulic Servos

FRANK J. HUDDLESTON
Westinghouse Electric Corp., Air-Arm Div.

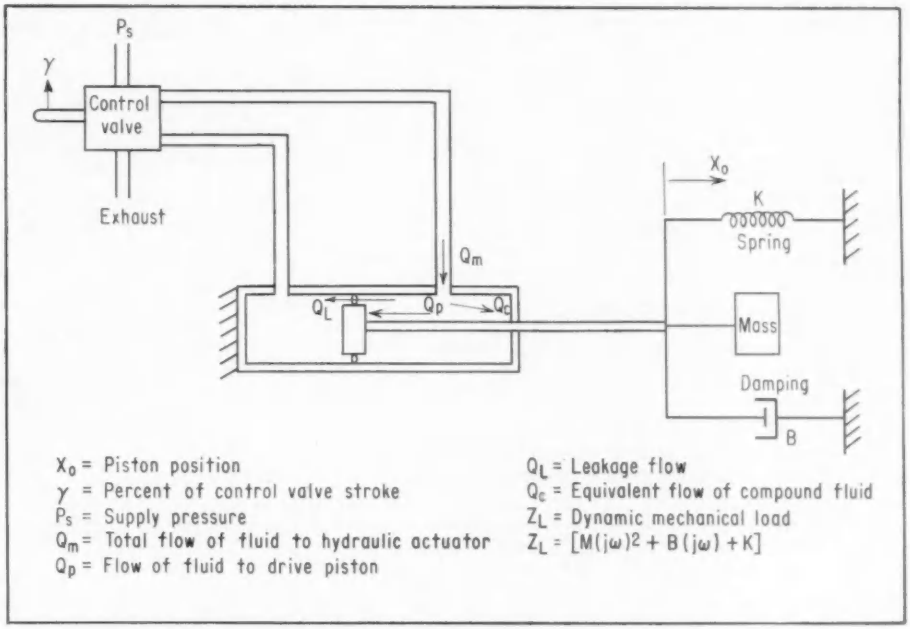


FIG. 1. Satisfactory hydraulic-servo performance requires a matching of control-valve flow-pressure characteristics with the hydraulic and mechanical impedances of the load (shown here).

A hydraulic servo (one is sketched in Figure 1) is usually only part of a more intricate control system. But it is one of the most difficult subsystems to alter experimentally. This means that required performance must be designed into it by pencil-and-paper analysis, a job complicated by the nonlinear effects of:

- orifices
- overlapped valves
- poorly regulated hydraulic supply

The graphical method presented here for determining the servo's transfer function gets around the difficulties of nonlinear analysis over an entire frequency spectrum by isolating the regions of operating frequency in which the characteristics of the hydraulic load on the actuator are constant. In addition, it spots the effects which do change the hydraulic load characteristics. The method was developed and used in the design of an automatic pilot for a military jet aircraft.

THEORY

The nonlinear relationship between fluid flow to the hydraulic actuator and the pressure drop across the control valve is plotted in Figure 2 as a function of the stroke of the control valve. Because the output of the control valve depends upon the characteristics of the load which it supplies, load lines can be constructed upon the curves, each load line representing a frequency region within which the transfer function is constant, even if not linear. Regardless of the shapes of the hydraulic load "lines" (they may become elliptical within certain frequency ranges), the

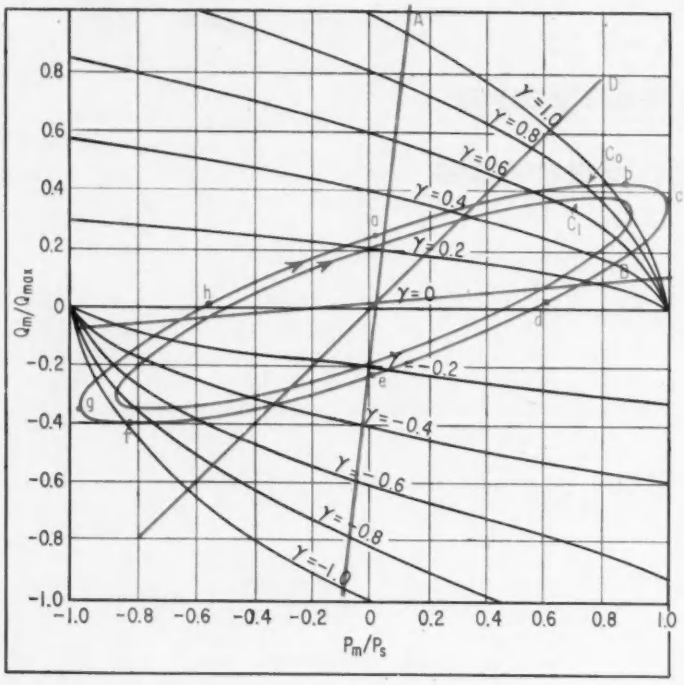


FIG. 2. The shapes and slopes of load lines superimposed on control-valve flow-pressure characteristics depend on the variation of load impedances with frequency.

flow to the actuator can be read from their intersections with the flow/pressure-drop curves for each value of input displacement.

The hydraulic impedence, Z_{pq}, is the relationship between the flow of fluid to the hydraulic actuator and the pressure drop across the actuator:

$$P_m = Z_{pq} Q_m \tag{1}$$

The pressure needed to drive a dynamic mechanical load, Z_L, a distance X_o is related to the actuator piston area by

$$P_m = \frac{Z_L X_o}{A} \tag{2}$$

Q_m is made up of : a flow, Q_p, of fluid to the actuator; a leakage flow, Q_L; and an equivalent flow, Q_c, of compressed fluid. Q_p equals the area of the piston times its velocity. Q_L equals the leakage coefficient, L, times the average pressure. Q_c equals the product of the fluid compressibility, σ, the volume, V_c, of the fluid under compression, and the rate at which the pressure is changing. Combining this information with Equation 2 and substituting in Equation 1 gives the expression for hydraulic impedance:

$$Z_{pq} = \frac{Z_L}{j\,2\pi f\,(A^2 + \sigma V_c Z_L) + LZ_L} \tag{3}$$

Z_{pq} is calculated at a frequency, f, and substituted in Equation 1 to calculate values of P_m and Q_m for a load line. To conform to the coordinates of Figure 2, first P_m is divided by P_{max} and Q_m is divided by Q_{max}. Thus the load line represents a normalized hydraulic load impedance,

$$Z_{pqn} = Z_{pq} \frac{Q_{max}}{P_{max}}$$

An example puts theory to work

Let the parameters of the subsystem in Figure 1 have these values:

M = 1.6 lb-sec²/in.
V_c = 1.4 in.³
A = 2 in.²
σ = 5×10^{-6}
L = 10^{-3} in.⁵/lb-sec
P_s = 2,500 lb/in.²
A_o, effective area of combined supply and discharge orifices = 2.5×10^{-4} in.²
ρ, fluid density = 8×10^{-5} lb-sec²/in.⁴
$B = 0$; $K = 0$

Q_{max} is the flow which passes through the supply and discharge orifices when the piston is unopposed and full supply pressure acts across the orifices. The orifice coefficient is taken as 1.25. Then,

$$\frac{Q_{max}}{P_{max}} = \frac{1.25\,A_o\,(P_s/\rho)^{1/2}}{P_s}$$

$$= \frac{1.25 \times [2.5 \times 10^{-4}\,(2{,}500/8 \times 10^{-5})^{1/2}}{2{,}500}$$

$$= 7 \times 10^{-4}$$

Multiplying Equation 3 for Z_{pq} by this normalizing factor and substituting numbers yields these values for Z_{pqn}, the normalized hydraulic impedance:

$$Z_{pqn} = \frac{1.6(j\omega)}{4+5\times10^{-6}\times1.4\times1.6\times(j\omega)^2 j\omega + 10^{-3}\times1.6\times j\omega} 7\times10^{-4}$$

$$= |Z_{pqn}| \angle \theta \tag{4}$$

Load lines can now be plotted from Equation 4 when it is solved for frequencies $\omega = 2\pi f$. At extremely low frequencies the subsystem will operate along load line B of Figure 2, since there is no restraining load in the form of a spring and very little pressure drop is needed to provide high fluid flow. When there is a spring load, the proper load line would look like line A. At slightly higher frequencies the flow is in phase with the velocity of the piston, while the pressure is in phase with the piston position. The phase of Z_{pqn} then is near −90 deg and the load line has an elliptical shape similar to that of one of the curves C in Figure 2. The particular ellipse depends on γ_{max}, the maximum percent of control valve stroke. The flow leads the pressure, and the direction of travel around the ellipse is counterclockwise.

Elliptical load lines are quickly constructed by solving Equation 4 exactly only at critical frequencies and then drawing smooth curves through the values. When one ellipse has been constructed for a fre-

BASE CURVE C_o
IS PLOTTED FROM THESE VALUES

Point	$\frac{Q_m}{Q_{max}} = 1 \sin \omega t$	$\frac{P_m}{P_{max}} = 0.4 \sin (\omega t + 34°)$
a	1 sin 0° = 0.00	0.4 sin 34° = 0.22
b	1 sin 56° = 0.83	0.4 sin 90° = 0.40
c	1 sin 90° = 1.00	0.4 sin 124° = 0.33
d	1 sin 146° = 0.56	0.4 sin 180° = 0.00
e	1 sin 180° = 0.00	0.4 sin 214° = − 0.22
f	1 sin 236° = − 0.83	0.4 sin 270° = − 0.40
g	1 sin 270° = − 1.00	0.4 sin 304° = − 0.33
h	1 sin 326° = − 0.56	0.4 sin 0° = 0.00

quency, others for different γ_{max} at that frequency are proportioned to it. In the example, $Z_{pqn} = 0.4/\underline{34}$ deg at $\omega = 500$ rad per sec.

Taking

$$Q_m/Q_{max} = 1 \sin (\omega t),$$
$$P_m/P_{max} = Z_{pqn} Q_m/Q_{max} = 0.4\ (1) \sin (\omega t + 34 \text{ deg})$$

The table lists values calculated for construction of base curve C_o in Figure 2. Curve C_1 for $\gamma_{max} = 1$ is proportioned to it.

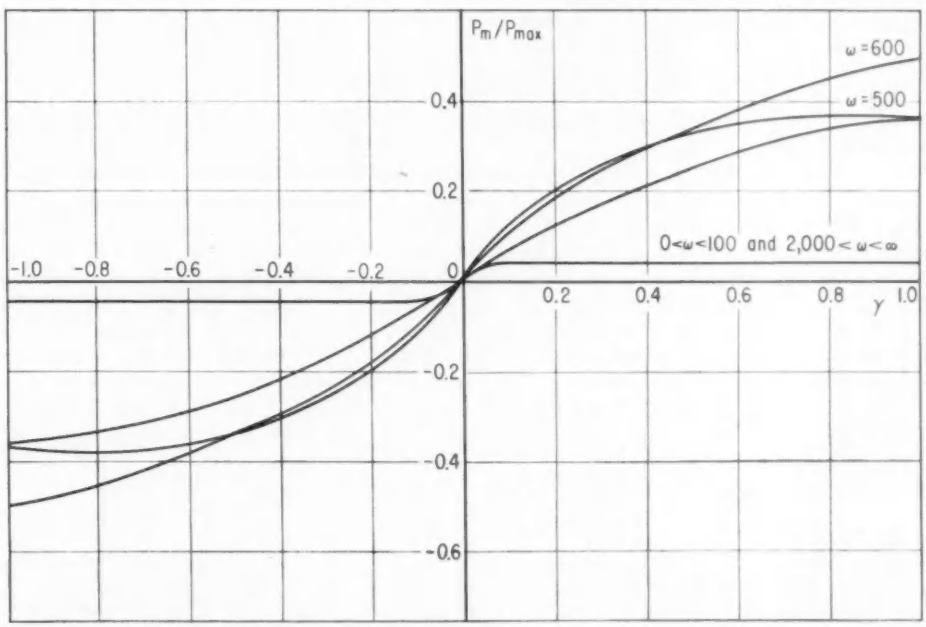
As the frequency increases further, resonance may cause the pressure to pull in phase again with the piston position and the load line to collapse again to a straight line. Because the load line depends on the characteristics of the load at the given frequency, its slope is not necessarily the same as that at extremely low frequencies. Load line D represents the resonance that occurs in this example at $\omega = 600$ rad per sec. At still higher frequencies the inertia term of Z_{pqn} predominates: the pressure is in phase with the acceleration of the output member, the phase angle of the hydraulic impedance approaches +90 deg, and the load line again becomes an ellipse. But the direction of movement along the ellipse is clockwise because the flow lags the pressure. At extremely high frequencies the compressibility of the fluid becomes the predominant factor and the phase angle of Z_{pqn} swings back to − 90 deg. Very little pressure is available to drive the load and the load line is similar to line B.

The response of pressure to valve stroke in the various frequency regions is plotted in Figure 3 by locating the intersections of load lines A, B, C_1, and D with the control valve characteristics. The nonlinearities are apparent at each frequency. To determine the actual output position X_v as a function of percent valve stroke, γ, at each frequency, the values of P_m obtained for Figure 3 are substituted in Equation 2.

One can consider the effect of valve overlap on the transfer function of the hydraulic system by redefining the constant γ curves of Figure 2. If the overlap distance is 0.2 γ, the zero displacement curve would be labeled $\gamma' = -0.2, 0, 0.2$ instead of $\gamma = 0$. Likewise, each of the γ' curves would be relabeled $\gamma = +0.2$. The procedure for plotting output X_v as a function of γ would then be carried out in the manner just described.

Another nonlinearity that might be analyzed is the effect of a supply pressure characteristic that droops with increased fluid flow. Again the load lines would remain constant, but the P-Q curves of the control valve would be redrawn to include the effect of the poor regulation.

FIG. 3. The relationship between operating pressure and valve stroke is a nonlinear function of frequency



Custom-Designing Controllers for Time-Based Routines

THE GIST: The complex operating cycles of today's processes and machines mean added work for timers in automatic controls. In many cases, the timers themselves assume the proportions of full-fledged subsystems and even qualify for the more descriptive name of time-based program controller. The point has been reached where the designer must make simplification an objective. In this first of two articles, the author explains various techniques for translating time-based control routines into mechanisms that are accurate without being overly involved.

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The routines or programs built into a great number of automatic control systems operate on a time base. The key component in such controls is the timer which provides the command signals that, say, start an electric motor at time zero, open a valve at time zero plus 10 sec, etc. In recent years, the time-based routines of certain processes and machines have become so lengthy and complex and have required such levels of accuracy that timer technology has had to advance rapidly. The point has been reached where in certain applications the "timer" is actually a major piece of control apparatus that is more fittingly described by the term, time-based program controller.

The basic problem in the design or selection of a time-based program controller is to provide:

1. Sufficient capacity for the length of the routine and the number of control actions to be initiated.
2. The accuracy needed to assure the occurrence of control signals within the allowable time limits.

It will be seen in the following discussion of the design of program controllers that these objectives often require an especially high level of ingenuity from the control designer. Often, to prevent a program controller from becoming excessively costly, intricate or bulky, he must reach for new components and techniques not ordinarily thought of as being associated with the "timer" field.

Programmer forms

One of the simplest time-based program controllers is the synchronous interval timer, Figure 1. Here, a motor (not shown) drives a shaft carrying a disc and cam piece. The mercury switch is actuated at an instant of time determined by the position of the cam along the circumference of the disc and by the shaft speed. In multiple timers, several cam discs are arranged on one shaft to actuate a corresponding number of switches. Multiple timers have an added feature in that adjustments can be made in the time relationships among the pulses produced by the various cams.

In a majority of cases, mechanical contacts replace the mercury switch because of their better timing accuracy. Multiple timers usually have adjustments for permitting changes to different switching patterns without taking the whole program controller apart. This can be done by providing two settable cams for each switch, one governing the beginning and the other determining the end of the "on" portion of the cycle. By proper cam design, it is possible not only to switch something on or off, but also to realize signals of predetermined amplitude and slope.

Program controllers incorporating such cams are used, for example, in the control of temperatures in the chemical and glass industries. Curing ovens, heat-treat furnaces, and cooling ovens rely on temperature programming, whereby temperatures are made to increase or decrease slowly along a defined curve over a time base of hours, days, or even months. In such program controllers, the amplitude of the motor-driven cam is sensed by a lever mechanism and then translated into an electrical value by a potentiometer or variable inductance. The voltage obtained actuates a feedback control system containing a temperature transducer, which

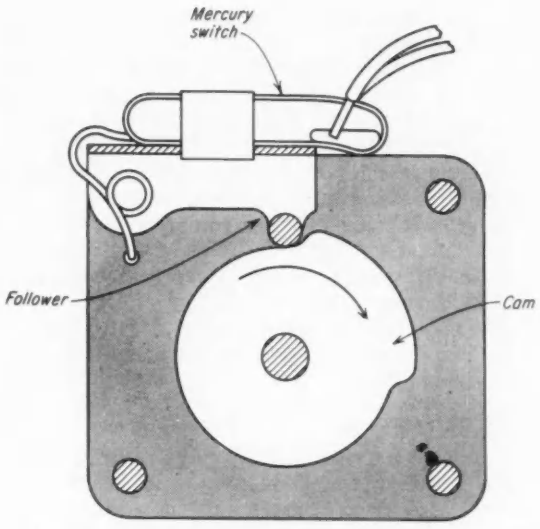


FIG. 1. Synchronous timer with cam-operated mercury switch.

positions the power controller of the heater. Where desired, a number of cams can be provided to simultaneously control other temperatures and auxiliary functions, such as starting motors or opening oven doors at the end of the cycle.

As versatile as the synchronous timer is, some of today's applications tax its capabilities in two areas: accuracy and capacity. The latter characteristics are closely related as can be seen by consideration of a factor known as "relative accuracy"—a criterion that came into being because accuracy requirements cannot be properly evaluated without relating it to the duration of the routine (or the capacity of the program controller).

For example, it may be more of a problem to actuate a switch after 30 days with an accuracy of plus or minus 1 min than to hold a 10 sec interval to plus or minus 0.01 sec, because the relative accuracy, which may be defined as the ratio of permissible tolerance to duration, is greater. The relative accuracy, a, in each of the two cases is:

$$a_1 = \frac{1 \text{ min}}{30 \text{ days}} = 2.315 \times 10^{-5}$$

$$a_2 = \frac{0.01 \text{ sec}}{10 \text{ sec}} = 10^{-3}$$

The reciprocal value of relative accuracy is called resolution, and is numerically identical to the number of time increments that must be accommodated by the memory. In the first of the above problems, 43,150 increments are needed, while in the second only 1,000 increments are required. The simple cam is largely inadequate for applications involving so many discrete increments because its readout accuracy is usually on the order of plus or minus $\frac{1}{64}$ in. (tantamount to a spread of $\frac{1}{32}$ in.) including the pick-off mechanism. With such accuracy levels, the length of a cam needed in the first example would have to be 43,150/32 or 135 in., and even in the second problem would entail a trace of 1,000/32 or 31.26 in. It is difficult to accommodate such long cam paths (or grooves) on a single wheel or cylinder. While it is possible to hold the cam accuracy to a better value or to arrange the path in the form of a helix or spiral, such expedients are probably of only marginal advantage.

The most practical way of achieving a very long path is with the use of some type of tape, accommodating mechanical, magnetic, or photographic traces. In recent years, mechanical traces in the form of punched tape or cards have been developed to a high degree of perfection and versatility, as evidenced by successful experience with equipment such as office machines, computers, and Teletype machines. And mechanically-grooved plastic tape seems feasible for special purposes where expense is an important consideration.

In addition to capacity for the prescribed length of trace, program controllers must also have sufficient lateral capacity to carry the number of routines that occur simultaneously. Multichannel control is, of course, possible with mechanical devices. For example, many cams or guides can be placed on a single synchronously driven shaft, while tapes can be fitted with several parallel traces. But if more than, say, 10 or 20 channels have to be taken care of, and particularly if there are different cycling and accuracy requirements, the problem is probably too involved for simple mechanical traces and the designer should look for other means.

Electrical components functionally equivalent to the mechanical devices described can be assembled to produce program controllers that are superior for many applications. For example, the equivalent of a "mechanical trace" in the electromagnetic realm is a magnetic recording on tape. This technique has the advantage that several traces can be put on a broad tape side by side. In addition, it is possible to multiplex by using the signal to modulate a constant frequency. Thus several modulated frequencies can be recorded on one trace, then separated from each other at readout time by filtering. A rather large number of channels can be accommodated with these means, making possible extremely complex signal patterns extending over long periods (a single tape can run for several hours).

In view of the multiplicity of hardware available for the memory and other functions, the designer should list all the possible solutions to the programming problem, analyze these possible solutions, and, then select the one which suits the case best. The task of finding these possible solutions—not necessarily practical solutions at first—can be facilitated by the "total block diagram of programmers" that will be explained later in this article. A pitfall

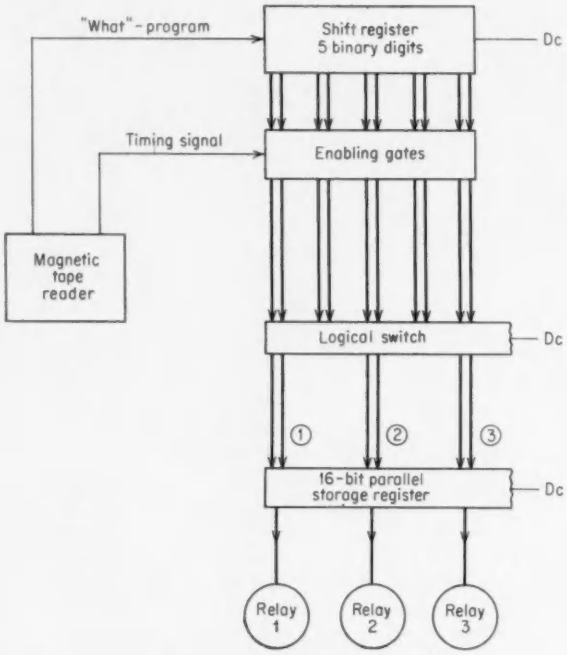


FIG. 2. Digital program controller employs magnetic tape with two information channels.

to be avoided is the occasional tendency to design involved program controls where simpler approaches would suffice. This tendency is particularly evident when prejudices for or against certain types of components exist. The penalty for such prejudice may well be excessive cost or complexity brought about as a result of lack of compatibility.

Assume, for example, that magnetic tape has been chosen for the memory and mechanical switches for the final contacts of a given control. Choice of the first is based on its flexibility with respect to the stored information and because it is a familiar medium in the electronic field. The switches were selected because of their ruggedness and simplicity. It is found, however, that magnetic tape and mechanical switches are somewhat incompatible so that an intermediate arrangement consisting of an amplifier, a step motor, a shaft with discs and cams, and levers actuating the switches is needed. The resulting system actually has two memories. The first memory, the tape, represents the "event" memory; the second one, an array of cams, represents the "what and how long" memory. Such an instrument may be too complex and not very suitable for many applications. On the other hand, its flexibility suits it for complicated signal patterns.

The use of double memory, including the "event" and the "what and how long" functions just mentioned, is essential for extremely long and complicated control routines. Some channels can be used to direct or to process in a special way the information of other channels. For instance, the first channel of a multichannel program controller may carry a certain signal pattern, while a second channel directs this signal pattern first to station No. 1, then to station No. 2, and so on. The pattern may be changed for the different stations, or treated (amplified, rectified, etc.) in different ways. This principle can be combined with multiplexing. Another form of double-memory control contains a stepping switch that receives pulses from a geared-down contactor. Every time the stepping switch moves, the tape is run for a set time during which the recorded signal is played back and directed to the various components that are to be actuated. Direction can be effected by a second contact array of the stepping switch.

Digital techniques

The tape traces considered up to this point have been regarded as being comparable to those of cams. Such traces are described as analog in that the function to be controlled is represented by distances from some reference line. These distances change continuously and in infinitely small steps. Purely analog traces have their limitations even if tape, with its costly transport mechanisms and rather involved playback apparatus, is used. Generally, analog traces cannot combine very long running times with high accuracy, and are not suitable for complicated signal patterns. But they are often the simplest and hence the most practical solution.

The versatile digital-computer techniques have also been applied to the task of program control. Of the large number of possibilities evolved, two that are typical of what can be done will be described here. The first employs digital techniques with magnetic tape, Figure 2. Assume that there are 16 circuits to be controlled, each through a relay that can be switched on or off at any time within certain limits of running time and accuracy. Five-digit binary numbers are recorded on tape, which carries two information channels. Data on one channel determines which relay will be energized while timing signals are recorded on the second channel. These are equivalent to a "what" memory and an "event" memory, except that the two memories here are acting simultaneously and not sequentially.

The numbers on the first tape channel are fed into a five-bit shift register, and, when a timing signal is produced by the second tape channel, through parallel enabling gates to the logical switch. The logical switch is a diode matrix that directs the signal to the particular relay identified by a binary number. The appearance of binary 01011 (decimal 11), for example, admits voltage to relay No. 11. The pulses pass through a 16-bit parallel-storage register that performs the function of holding the relay until the signal for its release comes along. This signal is represented by the corresponding binary numbers from 16 to 31.

The second example is a digital program controller that does not use tape and has no moving parts. Employing electronic switches, the circuit in Figure 3 operates as follows: a digital clock or steadily increasing binary counter feeds an array of diodes and switches. Each diode is connected to either the 0 or 1 output of a binary counter stage, depending on the position of the switch, which is set manually beforehand. The switch positions establish the program. The output channels of the diode matrix are connected through buffer circuits (not shown) to the terminals of electronic switches or relays. For an output channel to be at $+E$ volts, all of the diodes wired to that channel must be connected to outputs of counter stages, which are high at the moment. The switches or relays can be actuated accurately at any time within the capacity of the counter.

A general shortcoming of digital programmers is the large number of components required. Depending on the number of channels and the resolution (number of time increments), several hundred transistors and diodes may be employed. And, although the programmers need not be bulky or heavy, they will be expensive and justifiable only where their advantages of speed, flexibility, accuracy, and insensitivity to vibration are important. These advantages are offered particularly by the tapeless programmer. Because of the addition of the tape mechanism to an otherwise purely electronic scheme, the tape controller is more complicated and more prone to mechanical failure, but is more suited to handle very extensive programs.

As stated before, a magnetic tape can be considered as the functional equivalent of a mechanical tape. Similarly, the components of a digital program controller not only are similar to, but also can actually be replaced by mechanical parts. It is quite interesting to test this statement by replacing the electronic counter of the tapeless digital programmer with a mechanical counter.

Figure 4 shows a schematic of an ordinary mechanical counter of the odometer type, driven by a motor or some mechanical input. Notches are provided on the counter wheels, which are arranged so that when a certain number is shown on the counter, all notches face in one direction. Upon such alignment, an appropriate number of coupled levers fall into the notches and thus actuate a switch. The notched counter wheels are, of course, adjustable. In this arrangement, well known from so-called predetermining counters, A, B, and C are the stepwise-moving, notched wheels of the odometer-type three-digit counter, whose positions indicate decimal numbers. Coupled levers G_1, G_2, and G_3, under the influence of a compression spring, can move to the right only, when and if all levers hit a notch. In this case, the notches can be set to correspond to any whole number between 0 and 999. The horizontal bar hits the trip rod of the snap-action switch which, at a later time, may be released by a duplication of the arrangement described; i.e., by a second counter with levers G_4, G_5, and G_6.

The schemes depicted in Figures 3 and 4 have the following components in common:

1) A digital counter.

2) A "coincidence device", which functions when and if coincidence exists between a number set into this device, and a number reached in the counter.

3) Switches actuated by the coincidence device through suitable intermediate means.

The similarity of these two approaches seems to be more interesting than the evident differences. Both have their merits. The mechanical counter is simple, inexpensive, and easy to set. It is reliable for moderate speed requirements unless exposed to severe vibration. A counter for each switching

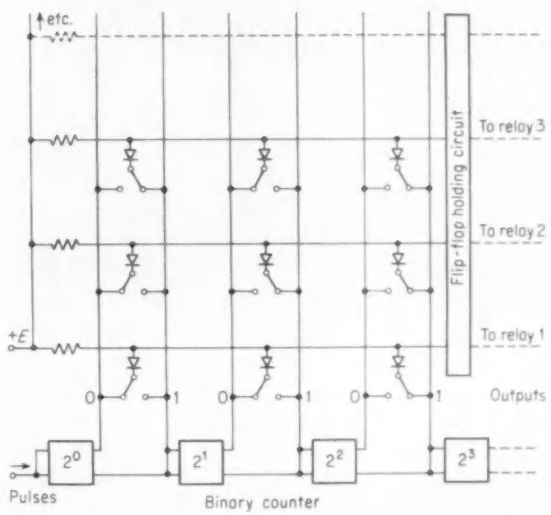
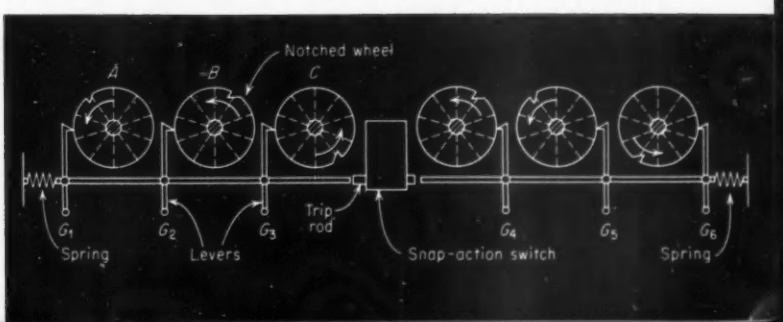


FIG. 3. Binary counter serves as a digital clock in this controller.

FIG. 4. Mechanical counter for compressing long traces into a minimum of space.



function is required, however, whereas the electronic program controller needs just one electronic counter for any number of output channels, and is much better suited for complicated signal patterns.

While the electronic and mechanical counter schemes described here rate as digital, a simple cam timer is purely analog in nature. However, the two principles involved are not so far apart as it may seem, and the field in between appears to be fertile

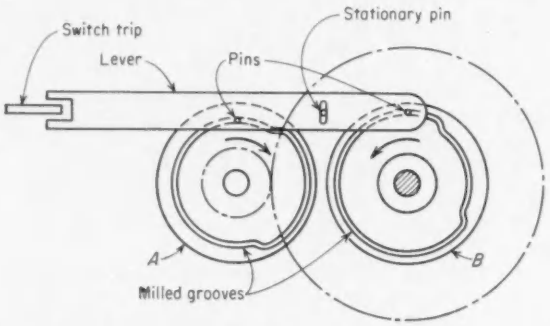


FIG. 5. In two-speed mechanical timer, the switch is actuated only when both cam pins are shifted simultaneously.

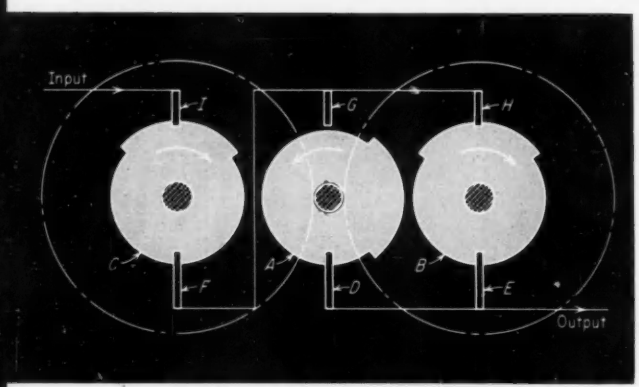


FIG. 6. Two-speed principle applied to gliding-contact timer.

for a variety of hybrids. The designer should not overlook possibilities which present themselves here, unconventional as they may sometimes be. A hybrid analog-digital system can, for example, help overcome the principal disadvantage of a simple analog system, trace length, which may be quite awkward if the number of time increments is high. In some operations, only the beginning and the end of a trace actually do something, while the length in between performs merely a holding function. This opens the possibility of driving the program controller at rated speed only when the trace extremities are being read and stopping or slowing the drive during hold periods. Such action can be provided by means of a step motor, fed either by a continuous sequence of pulses or by an event programmer which produces a pulse only when an event is to take place. The result is a marked reduction in the trace length needed.

A step motor driving a shaft with a number of cams that actuate mechanical switches can be compared directly to the controller of Figure 3. The action of the switches corresponds to the output of the diode array, and that of the constant-amplitude cam lengths to the functions of flip-flops or holding relays. When an event programmer is used, the cams and the related pick-off levers perform no timing function. Such an arrangement suffers from a superfluity of components because the step motor, operating as a stepping switch, could be used as a programmer directly, with or without holding relays. Since the similarity of these programmer schemes to the digital electronic programmer in Figure 2 is so striking, the stepping-cam programmer can no longer be called purely analog. The stepping motor provides, at least in part, the properties of digital techniques. Moving an electrical or mechanical trace in steps affords higher accuracy than a continuously moving trace of necessarily limited length.

Two-speed controllers

Digital and analog techniques can be mated in a second way. Consider that the accuracy of a simple analog trace depends on the speed with which the beginning and the end are moved past the pick-off, and that total time depends on the length. By assigning these tasks to two traces operating at different speeds, a versatile class of controllers, designated as "two-speed", are evolved. These are comparable to two-digit counters and for this reason qualify as offsprings of digital techniques. Figure 5 shows one of the many possible forms of the two-speed principle. Discs *A* and *B* rotate on separate shafts and at different speeds, which are maintained at a fixed ratio equal to a whole number. Both discs have mechanical traces in the form of milled grooves, which are engaged by pins. The pins are attached to a lever guided through a slot by a stationary pin. The lever actuates the switch lever or contact spring when both traces produce an effective excursion at the same time; i.e. the left groove moves up and the right groove moves down. Excursion of only one groove is not effective. This design principle is easily adaptable to stacking and is fairly simple; yet it provides good accuracy in small space.

The same type of action can be achieved by gliding contacts or brushes on conducting paths. Under proper operating circumstances and with adequate design, gliding contacts can be made quite reliable. Good electrical contact is often maintained by heavy brush pressure and generous dimensions, and by designing for lower current levels. An adaptation of the two-speed method to gliding-contact systems is shown in Figure 6. The discs

are of conducting material. Center disc *A* rotates fast while discs *B* and *C* operate at some lower speed. Brushes *D*, *E*, and *F* make permanent contact with the discs, while brushes *H*, *G*, and *I* lead to the traces or "conducting cams". The wiring is connected in series-parallel, which incidentally corresponds somewhat to the arrangement of the lever in Figure 5. The fast disc controls both beginning and end of the switching function. Discs *B* and *C* are arranged to rotate in unison, but the cam on *C* is slightly displaced from that of *B* so that it makes contact sooner but breaks contact later. Also, the gear relationship between *A* and *B* is such that the A-G contact is made when the *B* cam is either making or breaking contact with *H*.

Now, at the start of a cycle, cam *C* makes slowly, but without effect since cams *A* and *B* are slightly counterclockwise of their make point. Shortly thereafter, cam *A* makes at high speed to set up the start pulse. Then, cam *B* makes, establishing the hold circuit. At the end of the cycle, cam *B* drops out first while the output circuit remains made through cam A. Then contact A-G is broken at high speed. Cam *C* drops out before cam *A* has had time to reach *G* again.

This program controller or timer is compact, simple, and accurate. It can be stacked to accommodate a number of output channels. Change of the program is by exchange of discs. In certain cases it is advantageous to reverse the design so that the program discs are stationary. The timer is rather insensitive to vibration, particularly if filled with oil. For high current loads, relays may be employed. Although not purely digital (the setting can be altered in infinitely small steps), this device does have one of the main features of digital techniques: the value of a number, function, or occurrence depends on its position in a digital fashion.

The programmer of Figure 6 can be developed into a multiple timer having only one or two gliding-contact devices, by dissecting the conduction cams into arrays of single contacts, thus obtaining two

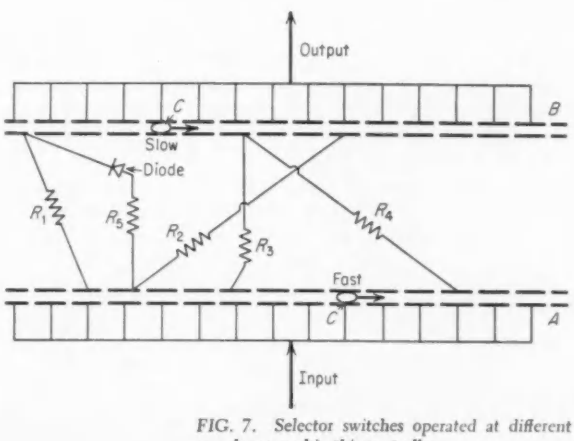


FIG. 7. Selector switches operated at different speeds are used in this controller.

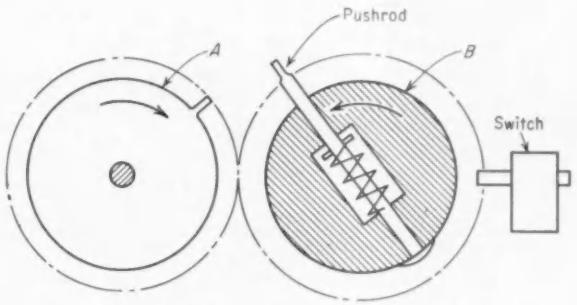


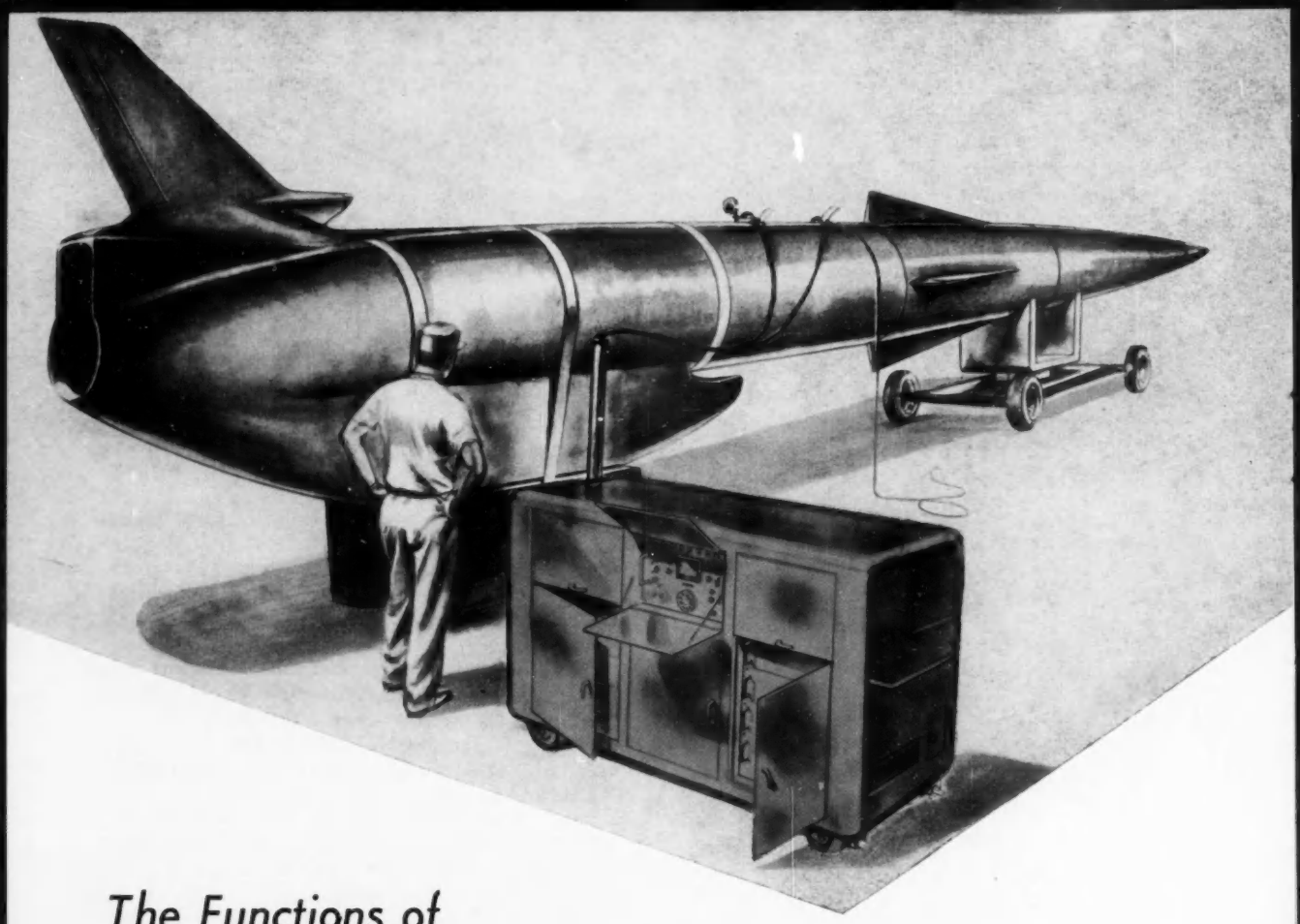
FIG. 8. Two-speed positioned gear timer.

multiple-pole rotary switches which rotate again with two speeds. Two single-deck multiple-pole switches with n contacts each can switch up to $2n-2$ relays or even more. The relays are hooked up between the poles of the switches. Figure 7 shows the principle. *A* and *B* represent the contacts of the two multiple-pole rotary switches and *C* indicates the gliding contact fingers or rollers. R_1 though R_5 are relay coils wired in places corresponding to the time at which they are to be actuated. If a circuit such as the one between R_1, R_5 and R_2 occurs, a diode may be used to block reverse current which may trip relays (here R_1, R_2 and R_5) at unwanted times—in wrong finger positions. This method increases the number of possible positions to more than $2n-2$.

This timer is very small since it needs only two rotary switches if the release of the relays is not a factor, and four switches if it is. Because the switches are commercial types, the timer can be assembled from off-the-shelf components. It has high resolution and adapts to many programs.

Another scheme that uses a "two-speed method" and affords precise timing, is shown schematically in Figure 8. Two discs or drums that are easily stacked on shafts are driven by two gears, each with slightly different number of teeth, say 99 and 100. A switch is mechanically actuated whenever the protrusion on disc A and the pushrod through disc B are aligned. Note, however, that this alignment occurs only once in each 100 revolutions of the 99-tooth gear. Both protrusion and pushrod can be positioned as required. The timing is very accurate and affords high resolution in small space. Setting is not too easy, however. Release of the switch or relays actuated by the switch may be accomplished by a second gear system.

This brief review of timers and program controllers serves to illustrate the many combinations that can be put together to solve any given application problem. In every case, however, there is really but one optimum solution, which can be realized only by careful evaluation of known techniques. The second part of this article will describe the "total block diagram", a useful aid that establishes a guide to systematic evaluation and design of controllers.



The Functions of Guided Missile Checkout Systems

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As weapons systems grow more complex, the problem of satisfactorily checking them out with unskilled personnel in a tactically feasible time becomes tougher and tougher. The military is resorting to integrated automatic go/no-go test sets because they remove most of the dependence on the operator. This article describes the general functions and equipment of automatic test sets used to check out missile systems in the field.

An integrated weapons plan encompasses the diverse activities that culminate in delivery of a projectile to the target. Closely interwoven within this network are the limitations and capabilities of the factory production unit, personnel availability and training, test environment considerations, and the pressures of an intensive aircraft development program. These modify and shape the design of the test set so that it is not only capable of the job assigned to it but is also compatible with maintenance procedures, factory test techniques and tolerances, and the logistic supply system of the military services.

In its ultimate form the automatic test set may run through a test program with the operator doing nothing but connecting cables and starting the sequence by throwing a switch. Although feasible, this may prescribe a degree of system complexity that a field operational unit cannot justify. The test program will, more likely, combine a certain degree of electronic and mechanical complexity with a modicum of operator tasks.

What the automatic test set does

Its basic job is to demonstrate overall performance by an "end to end" test. This is analogous to feeding a manually simulated signal into the front end and measuring the outputs. But it is much more comprehensive, for it tests a large number of signal levels and it explores system dynamic responses. Measurements of supply voltages and bias, crystal, and servo excitation voltages or currents that are important to system performance supplement the overall test.

In this article a missile subsystem is a major unit of a missile, such as the complete radar unit. A missile subassembly is a distinct part of a subsystem. In a radar unit this might be the directional coupler, the transmitter, or the receiver.

A simulated signal is programmed into missile subsystem inputs and reference signals are established for comparators. The output of each subsystem output is evaluated for the different input conditions. The test set indicates acceptable performance of each subsystem by extinguishing no-go indicator lights provided for the purpose and by recording the programmer test results. It records other data pertinent to the test conditions at the same time. When the test set finds a malfunction, it stops automatically to prevent damage to system components by continued application of test voltages. A malfunction stop then resets the programmer to the first position of a sequence; in this way the fault is isolated.

The fault isolation program pinpoints malfunctions at the missile subassembly level. The number of subassembly test points depends on the complexity of the weapon system, but there must be enough points for evaluating the performance of each subassembly. The test set programs through the fault isolation sequence, stopping at the defective subassembly. A digital indicator shows the test number of the malfunctioning subassembly so that the operator may locate and remove it.

Figure 1 shows the general arrangement of automatic go/no-go test sets. Test components are divided into functional subassemblies which most readily accomplish diverse test requirements. The control panel, shown in Block 1, starts, stops, and resets the test. Block 2 contains the automatic programmer, which sequences the input signals and the quality decision elements in synchronism. The programmer also provides control signals for the weapon system and the test equipment itself. All auxiliary equipment requiring sequencing for the automatic test is connected to the programmer. The intelligence simulator (Block 3) supplies the stimuli to the system under test. Block 3 might, for instance, set up an RF voltage which simulates the input to a radar and which varies over the predicted input range. Transducers or preparatory circuits in Block 4 convert subsystem responses to voltages suitable for comparison with reference voltages. Responses may be ac or dc voltages, pulses, or any other type of signal. Blocks 5, 6, and 7 represent the quality decision elements. The reference source (Block 5) develops reference voltages against which the comparator (Block 6) checks the transducer outputs. The evaluator (Block 7) imposes tolerances upon the outputs of the comparator and makes the go/no-go decisions, which it then supplies to the display panel (Block 8). Power supplies for both the subsystem under test and the elements of the test equipment are shown by Block 9. Block 10 shows self-check provisions, which verify the comparator action by nulling the reference input to the comparator. Precision deviations on the self-check reference automatically check the tolerances.

Common units handle a large number of the test requirements. The comparator, evaluator, programmer, and reference signal sources are usable for all tests; stimuli sources and transducer units are

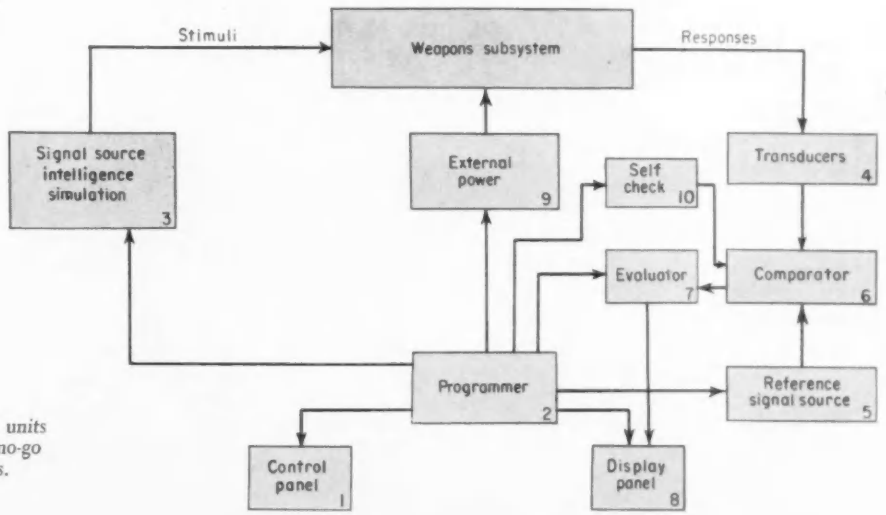

FIG. 1. Ten functional units make up automatic go/no-go missile checkout systems.

more restricted in their applications. Test program designers can do much to make these elements adaptable to testing more than one type of aircraft or missile. Transducers are often very simple, a resistance potentiometer satisfying the requirements of many applications. Other transducer units with extensive applications include pulse height discriminators, frequency discriminators, rectifiers, and differential amplifiers.

Test methods and devices

Comparator. A one- or two-tube device may satisfy the basic requirement for an extremely simple comparator. However, transducer outputs can range from several volts, in which case the two-tube device suffices, down to millivolts, when considerable amplification becomes necessary. For reliable operation and realistic accuracy, amplifiers must be highly stabilized; this increases the complexity of comparators. The stability requirement eases considerably, however, if both the measured signal and the reference voltage are amplified in a common channel. With an arrangement of this kind, changes in amplifier gain will not change the relations between reference and signal voltages. Though the magnitude of the deviation indicated between the two becomes a function of the amplifier gain, this is of no consequence when a go/no-go indication is required. Figure 2 shows a widely used go/no-go comparator circuit with common channel amplification. It includes the evaluation function shown in Figure 1. High and low limits set into the two reference-signal channels provide reference sources for comparison. The measured quantity is applied to each section of the chopper so that each channel derives a square wave with the phase relationships shown in Figure 2. Because the circuit operates on phase relationship alone after the chopper makes the comparison, there is no stringent requirement for amplifier gain stability. If the square waves are out of phase, which would be the case when the signal is outside the tolerance limits, the relay control tube fires, indicating no-go. This type of comparator-evaluator indicates go/no-go, but not the nature of the out-of-tolerance deviation. A modification of the basic circuit does.

Programmers. Several methods are available for programming automatic test equipment. A cam actuator driven by a synchronous motor, used when the total number of tests is small, is not sufficiently versatile or adaptable to design changes. More sophisticated, as well as more suitable for complex switching functions, is a generator consisting of a synchronous motor driving a cam-switch arrangement or an electronic multivibrator. Its pulsed output drives a multiple-bank stepping switch or series of stepping switches. The stepping switches in turn control function relays or, if the switching current is low, switch the test set conditions directly. Both of these programmers lend themselves well to the control of signal sources, comparator-evaluator circuitry, and the power sources. The stepping switch approach has an added advantage: it can be arranged in series-parallel combinations to increase the capacity of the programmer.

A punched-tape operating in conjunction with stepping relays is used for more complex programming. The excellent adaptability is very important when system design changes are expected. Paper tapes used in this application have a minimum life of several thousand cycles. They may readily be prepared from circuit diagrams with manual punches. In an interesting extension of this approach, the program tapes are prepared automatically from IBM cards when the cards form a part of the design records for the weapon system. The tape sequences the stepping relays and provides instructions for other units. To avoid great tape lengths for warmup periods, the tape can instruct relays to turn off the tape motor and start a timing motor. When the timing motor has run through the warmup period, it restarts the tape mechanism which then continues the program.

Magnetic tapes may be used, but their information storage capacity is not required for the relatively simple test processes; thus their added cost and complexity are not justified.

The programmer can do more than establish test-time sequences. It may serve as the equipment instruction center, setting up the operating characteristics of all of the test-set building blocks for each test, making it practicable for one test set,

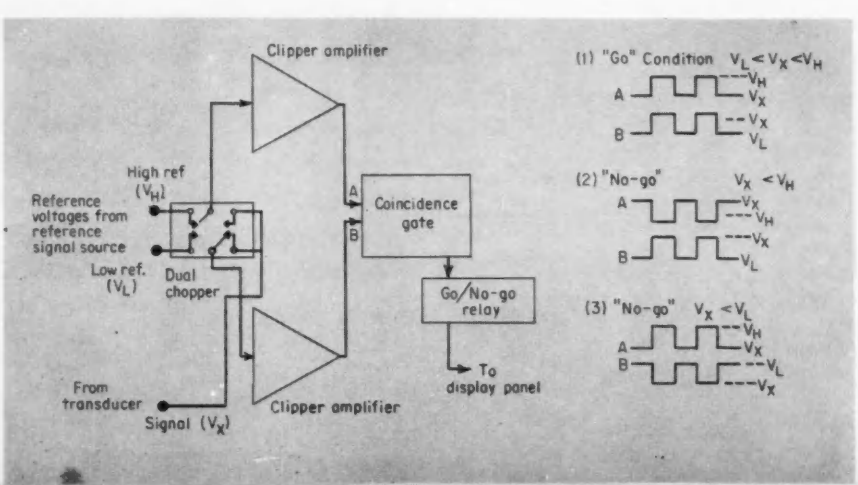

FIG. 2. A go/no-go comparator circuit operating on phase relationships does not require amplifier gain stability.

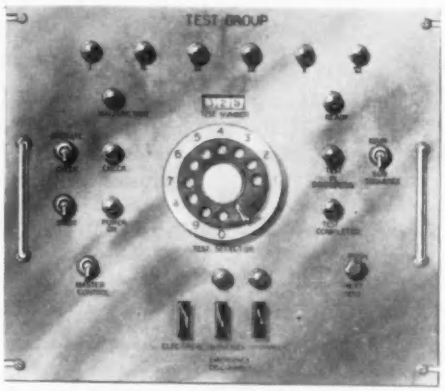

FIG. 3. Only the operational elements required to start the test and indicate performance are assembled on the control and display panel.

without modifications, to test a large variety of equipments. This makes it necessary, however, to design into the test set subassemblies (comparators, signal sources, etc.) sufficient versatility to handle the requirements of anticipated missiles. All that would have to be done to adapt the test set to a different subsystem is to insert a new program tape.

Stepping switches translate the program logic into working functions. To assure performance in tough environments, particular care must be taken in selecting these switches. Typical stepping switches have plated contacts immersed in an hermetically sealed oil bath. Taper pin terminals simplify the wiring process and reduce terminal-board size without running the risk of short circuits at soldered joints. The function relays used in the programmers are hermetically sealed, plug-in relays with hold-down clamps which conform to JAN or MIL specifications. The circuitry used in all programmers includes fail-safe features, and when stepping switches are used in multiples, a synchronizing check of continuity is made through a particular contact of all switches. Should the switches be out of position, a no-go indication will show, and the test will stop.

Control and display unit. To avoid confusing the operator, all controls and indicators not required for the test program are hidden from view. The control and display panel thus contains the minimum number of elements of the simplest form to accomplish the test objective. Figure 3 shows a typical panel. Only a study of the requirements will determine the exact quantity and type of hand controls; a minimum assemblage, however, must include:

• MASTER CONTROL—This toggle switch controls the primary power to the test set and to the system under test. It will also start any auxiliary equipment required for the test program, such as dc power units or compressors.

• START SWITCH—Starts the test program after warmup and stabilization. From this time until completion, or until detection of missile subsystem malfunctions, the operator does nothing but watch. The START SWITCH may be a momentary contact type.

• MAIN-SUBSEQUENCE SWITCH—It is normally in the MAIN position, when the test set will program through an end-to-end test for each electronic subsystem. Only in the event of a malfunction would it be necessary to operate this switch. In the SUBSEQUENCE position tests are made of individual subassemblies, starting at the first subassembly of the subsystem which failed.

• OPERATE-CHECK SWITCH—As part of the test program, the test set automatically checks its own circuitry at frequent intervals. However, by flipping this switch to CHECK, the operator can check the test set performance at any time, particularly when a malfunction indication is presented.

• EMERGENCY DISCONNECT—For disconnecting all primary power sources if a system failure or unsafe condition occurs. It may actuate dynamic braking or pressure relief devices.

• TEST DIAL—For rapid access to a particular test; the operator dials the appropriate test number indicated in a table of test positions.

• NEXT TEST SWITCH—If a test dial is included, this pushbutton permits the operator to reach the next test position rapidly. Both the TEST DIAL and the NEXT TEST SWITCH are useful in test programs which include manual adjustments for optimization of the systems being tested.

Indicators are normally restricted to lamps and a digital indicator. However, for subassembly adjustments, the indicators also include a lo-go-hi meter; that is, a meter with the lower and upper portions of its scale shaded to indicate out-of-tolerance measurements. Normal indicators include:

• POWER ON—Both the test set and the subsystems are on standby.

• READY—Test set has made internal checks and has determined that all connections are properly made; the warmup period is over, primary power sources are properly adjusted, and the self-check sequence has been completed satisfactorily.

• TEST IN PROGRESS

• TEST COMPLETE

• CHECK—On continuously during the test program, this light indicates that all self-checks have been completed satisfactorily. It will go out if an internal failure occurs or when the OPERATE-CHECK SWITCH is in the CHECK position, and will come on again when the self-check, thus started, is finished.

• GO INDICATORS—There is one go light for each subsystem plus one for the fault isolation sequence. If the missile has eight subsystems, there are nine go indicators. All no-go indicators are lit at the start of the test and are extinguished sequentially as the subsystems pass their tests.

• MALFUNCTION

• TEST NUMBER—Effective only during the fault isolation sequence. By checking the indicated test

number against a table of test positions, the operator determines which subassembly is defective. A coded system would eliminate this table of test positions. The first number of the code would designate the subsystem and the last two numbers the subassembly. For instance, 325 would indicate that subassembly 25 of subsystem 3 is defective.

Data processing and display

Missile test and control systems use both analog and digital techniques. Digital systems provide the greatest accuracy and have demonstrated their superiority in factory production tests of missile systems. They have one drawback, however: they cannot operate on "real time". But this does not appreciably restrict their use in the field because operational test-set processes are relatively slow

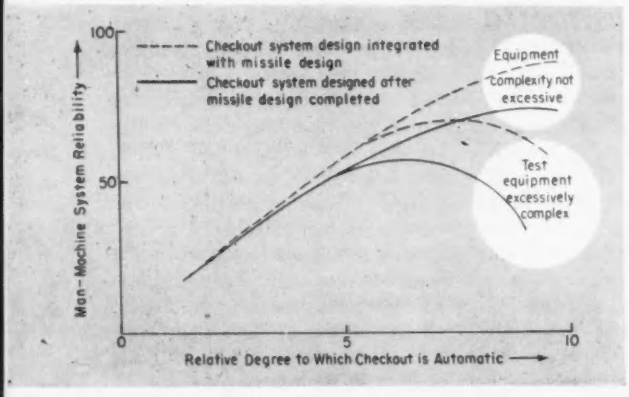

FIG. 4. Failure of over-complex test equipment diminishes overall system reliability.

(milliseconds rather than microseconds). The digital devices have a decided advantage whenever the measurements must be extremely precise. The major advantage is that they replace more complex subsidiary analog computing devices, in many cases with their mechanical counterparts. For example, an electromechanical keyboard, a simplified version of the common office adding machine, not only prints out test data in digital form, but also multiplies, divides, adds, and subtracts. Performing these arithmetic operations on functions that exist at different times is possible because the printer contains a storage commutator. On the other hand, analog equipment is superior in tests involving continuous, rather than sampled, evaluations, such as dynamic comparisons between input and output signals. This test is a real-time process.

The operator's display is described in the section headed "control and display unit". Since his skill is limited, it would be pointless to present more information to him. However, the test derives considerably more information than is presented by the display unit, and it is desirable to preserve this additional information for further analysis. This is particularly true of automatic factory test equipment, which require a record of test results to maintain realistic quality control and surveillance.

General equipment considerations

Static vs. dynamic testing. Static tests suffice for subassemblies and elements that contain limiters or circuits with simple gain characteristics. But where rate action, integration, and marginal phase-gain characteristics crop up, dynamic tests are called for. They are made extensively on missile systems with fins, valves, and other control elements that must be evaluated on a time basis. Dynamic tests may be more reliable and convenient than static tests on certain time-dependent components. For instance, a step function may determine the bandwidth of a video amplifier more simply than a frequency sweep.

Test equipment tolerances. Equipment errors of less than 10 percent of the tolerance imposed on a particular test response is a common goal. For example, a tolerance of 5 percent requires a test equipment accuracy of ½ percent, which is within the realm of precision instrumentation. The main burden of accuracy rests on the comparator, the evaluator, the transducers, and the reference signal sources. Reference signal sources present no problem because of the ease of applying standard cells or Zener diodes. Neither do analog comparators, many of which have accuracies better than that required, nor simple digital comparators, which provide better than 0.1 percent accuracy. Satisfying transducer requirements is hardest, but the fact that a potentiometer serves as a transducer helps considerably.

Reliability. Although the test equipment need not have as high a degree of reliability as weapons subsystems, it should be high enough to make it impossible for the equipment to designate a bad missile as good. This requires "fail-safe" equipment design practice. The converse error, of indicating that a good missile is bad, while quite undesirable, is more tolerable. Well-designed test equipment will establish a tolerance boundary that will make rare the cases of improper indication of missile readiness.

The designer must give assurance that the gains derived by reducing the operator skill requirements through automatic operation are not lost by requiring a corps of highly trained technicians to maintain the test set itself. The problem is closely related to equipment complexity, because the simpler the design the more reliable the test set will be and the more readily a lower-echelon technician may locate defects. Figure 4 demonstrates how, as the checkout system becomes more automatic, equipment complexity can reduce overall system reliability. The two sets of curves point out the benefit of careful integration of the checkout system design with the design of the missile.

Data Reduction Needs Differential Amplifiers

Dc amplifiers with differential input have real advantages in most data amplifier applications. In others they are the only answer. Some of the ways they can be used, along with their more important characteristics, are discussed here.

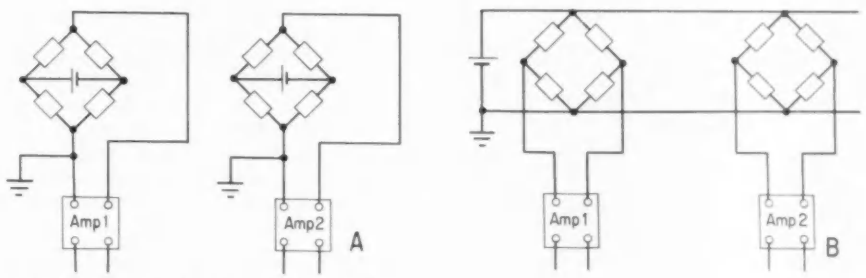

FIG. 1. Strain gage bridges with dc excitation:
A—single-ended amplifiers, requiring individual batteries for each bridge;
B—differential amplifiers permit a common battery or power supply.

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Differential amplifiers, in which neither the high- nor the low-potential side of the input need be grounded, may be used in data reduction for convenience, for accuracy, or out of necessity. Consider these in order:

Convenience can be seen in the ease with which the amplifiers are able to simplify the power supply for dc-excited strain gage bridges. Dc has several advantages over ac as the excitation power for strain gages, an important one being that there is no need for a reactive balance. If single-ended amplifiers are used to boost the strain gage signals, separate dc power supplies must be used to excite each bridge of a multiple-bridge installation, as shown in Figure 1A. This requires batteries, because one side of an ac rectifier power supply must usually be grounded. But with differential input amplifiers, all bridges may be connected to a common grounded power source, as illustrated in Figure 1B.

The accuracy of primary measuring instruments may be preserved. For example, in many industrial installations where thermocouples are connected to control or recording equipment, they must also be connected to data-logging equipment. The control and logging equipment will generally be at different locations, and if a single-ended amplifier is used, any difference in potential between the ground points of the two systems will be added to the amplifier input, Figure 2. The error can easily be a fraction of a volt, where only microvolts of error are tolerable. Using a differential amplifier with two leads to the thermocouple eliminates the error and the problem.

A differential amplifier, however, is sometimes an absolute *necessity*. Figure 3 shows a power bus which may be several hundred volts above ground potential. It is desired to amplify the potential difference across an ammeter shunt in the bus. Obviously, one side of the amplifier may not be grounded or the bus-to-ground potential would be added to the millivolts across the shunt. Only a differential amplifier may be used here.

Amplifier rejection ratio

Conventional amplifiers can be modified to give differential action, which is satisfactory for many purposes[1,2]. The rejection ratio (ratio of amplification of a differential signal to the amplification of a common signal applied between the two input terminals and ground) of such an amplifier may be several thousand to one. This ratio, however, is not satisfactory for many data-reduction purposes. Figure 3 represents an extreme example, where, with 100 volts of applied signal, a rejection ratio of 1,000 to 1 would still result in a differential error signal of a tenth of a volt—twice the total signal across a standard 50-mv shunt. A rejection

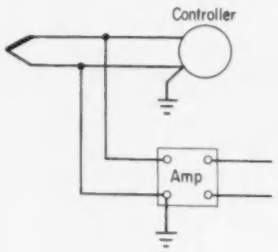

FIG. 2. Connecting a controller and amplifier to the same thermocouple results in multiple grounds with a single-ended amplifier.

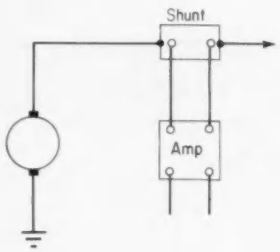

FIG. 3. Amplifying potential difference across an ammeter shunt in an high-voltage bus.

ratio in excess of 100,000 is required for this problem.

Similarly, for thermocouple amplification an accuracy of 1/10 deg F requires an accuracy of about 2.5 microvolts. To cope with ground potentials of 0.1 volt, the rejection ratio required would be 40,000 to 1.

The problem is still present with strain gages, though less severe, as Figure 1B illustrates. Lack of good common signal rejection in this case causes a change in supply voltage to appear as a bridge unbalance. With usual constants, a rejection ratio of 1,000 to 1 will give an error of 300 psi in steel for a 1-percent change in excitation voltage. Note, however, that a rejection ratio of 1,000 to 1 is fairly high for conventional amplifiers, and can be obtained stably only with special circuits.

To be widely useful, then, a data amplifier should have differential input with a very high rejection ratio—preferably in excess of 100,000 to 1. To get such high rejection ratios in a dc amplifier with stable gain requires that the input circuit be isolated electrically from ground. Practically, this means carrier amplification, and thus modulation of the input signal.

Signal modulation techniques

Carrier-type dc amplifiers differ in the method of modulation used[2]. Among these are:

- magneto-mechanical modulator—essentially a galvanometer movement, mechanically displacing the balance point of an inductance (or capacitance) bridge
- magnetic saturation modulator—a modification of the magnetic amplifier for the input to an amplifier, which may be of the vacuum-tube type
- nonlinear modulator—may employ rectifiers or amplifiers as the modulating element.
- switching modulator, or chopper

The first type, the magneto-mechanical modulator, is rather severely limited in response speed (to about 10 cps), is susceptible to mechanical vibrations, has relatively low input impedance, and is not generally as satisfactory for most purposes as some of the others. It was one of the early data amplifiers, however, and is relatively stable under favorable ambient conditions.

The magnetic saturation modulator has moderately good stability and fairly rapid response, but usually has a substantial carrier component in its output. It is difficult to filter the output adequately without seriously reducing the output response speed. A typical commercial unit has a stability of 20 microvolts per day drift rate; a zero shift of 100 microvolts for the temperature range from minus 67 to plus 165 deg F, a rise time of 0.01 sec to 99.5 percent response for a step input, a gain stability of 3 percent, and a peak-to-peak output ripple of 3 percent. This amplifier is in wide use for thermocouple and strain-gage amplification.

Nonlinear demodulators have long been proposed for dc amplification. Some recent circuits have been designed for transistors as modulators. They will probably never be satisfactory where zero drift rates in the order of microvolts per week are all that can be tolerated.

Of all the systems that have been proposed, the chopper-type amplifier still appears to have the greatest possibilities for data handling. The characteristics available can be illustrated by two typical amplifiers.

The first was designed to operate a d'Arsonval direct recording stylus, and thus can deliver considerable power (10 watts) into a low resistance load (7 ohms). The amplifier employs a chopper, producing a rectangular wave through a center-tapped input transformer. After amplification, synchronous contacts rectify the output through a second center-tapped transformer, giving full-wave rectification. With care in balancing the chopper and the impedance relationships in the circuit, gain stability, linearity, and ripple can all be held to about 1 percent. No progressive zero drift can occur in a chopper amplifier of this type, since the ac signal through the amplifier will only change with a change in the input signal level. Zero offset, due both to thermal emf's and to chopper actuating voltage pickup, can easily be held below 5 microvolts and is quite stable. However, a straight chopper amplifier can have a transient of the order of 10 percent amplitude for several chopper cycles following a step input.

The second chopper amplifier has relatively low output current capabilities (load resistance should be over 100,000 ohms), but has considerably better performance. It is essentially an amplified potential transformer —the voltage ratio is determined almost exclusively by the turns ratios of the input and output transformers, with the amplifier providing only the necessary power gain. Gain stability is 0.01 percent, both on a long-term basis and over the full ambient range from minus 67 to plus 165 deg F. Linearity is 0.05 percent of full-scale output, and the unloaded output ripple is 0.1 percent. The rise time to a step input is 99.7 percent complete in one chopper cycle (1/400th sec). As with other true chopper amplifiers, there is no zero drift. The rejection ratio is infinite for dc inputs, and still over a million at 60 cps. The output can drive a conventional single-ended dc power amplifier.

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CONTROL ENGINEERING GOES TO A MEETING

A Special Interpretive Report

Expanding Reliability to System Effectiveness

A significant trend in engineers' thinking noted at the recent reliability symposium in Washington prompted two Control Engineering editors to report on a new broad concept—system effectiveness. By analyzing the papers presented, the editors pieced together the significant factors in this new approach. Here, then, is a guide to:

- **elements of system effectiveness**
- **techniques for measuring reliability**
- **methods for predicting reliability**
- **improvements in system maintainability**
- **economics of system effectiveness**

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Control Engineering

A definition of reliability is almost as elusive as reliability itself. Meanings have ranged from the specific "mean time between failures" to a qualitative "how well the equipment performed". A new meaning seems to fit better the requirements of control engineers. Reliability is broadening into a concept of system effectiveness.

One of the advocates of system effectiveness as a method of evaluating equipment is the Military Electronic Systems Committee of Electronic Industries Association (EIA). Committeeman H. A. Voorhees, Western Electric Co., reasons for the broadened view.[1] He says, "Although mean time between failures has been accepted as a key criterion of reliability, it doesn't tell how valuable the equipment has been to the user. Satisfaction from the use of the equipment depends on a lot of factors, such as cost, performance capability, down-time, repair time, effects of redundancy, and effects of operating conditions and environments. These factors have different degrees of importance, depending on the type of system involved."

After a year's deliberations, the committee has pinpointed 10 elements to make up system effectiveness. Overall consideration of them provides a fuller measurement of performance, offers a realistic means for comparing systems. The factors:

1. mean time between failures (reliability)
2. average time to locate and repair a failure
3. percentage of time system is ready
4. percentage of successful missions
5. percentage of up-time
6. relative performance under saturation conditions
7. quantity and variety of spare parts required per unit time
8. system operability
9. personnel requirements
10. test and repair facility requirements

The relative importance of each of these depends on the particular application. In a missile-control system, for example, percentage of successful missions might be the most important element. In process-control equipment for a refinery, on the other hand, percentage up-time could be the leading factor. And in a giant computer, mean time between failures might be the best measure.

A CLOSE LOOK AT THE ELEMENTS

Mean time between failures is widely accepted as a statistical measure of reliability. C. M. Ryerson, RCA, explains why:[2] "It is possible to engineer adequately new equipment so that the contribution to equipment operational failures from other than random catastrophic failures is less than 5 percent. Therefore, it has become common to measure equipment reliability in terms of mean time between failures where occasional wear-out failures [missed by preventive maintenance] appear as indistinguishable contributions to the total."

Ryerson then points out how this becomes a tool to spot improper use of the equipment. "If use conditions become more extreme than was planned for in the design, wear-out failures can become an appreciable part of the total failures and the total failure level rises. Then any measurement of equipment reliability based on the capacity of the basic parts themselves when they are properly employed is a powerful tool to reveal the fact that they are being improperly stressed."

Average time to locate and repair a failure offers a measurement of the severity of the failure. How long it takes a maintenance man to discover that trouble exists, and then to trace the difficulty, varies for every different system. Actual data can be developed only as the system is operated, though a designer can sometimes predict trouble-shooting time accurately from past experience with similar designs. In general, the more complex the system, the longer the average time to locate failures.

The mean time between failures and the time required to locate and repair failures leads to two other elements of interest: **percentage of time a system is ready** and **percentage of its "up-time"**. The first is more likely to be applied to equipment used intermittently; the second to gear operated continuously.

To illustrate this, Voorhees describes two systems, *A* and *B*, equivalent in all respects (initial cost, mean time between failures, etc.) except repair time. He says, "If each has a mean time between failures of 50 hours, but average repair time for *A* is one hour and average repair time for *B* is 10 hours, then the user receives effective performance from system *A* 98 percent of the time and from system *B* only 83 percent of the time."

Another committee member, M. M. Tall, RCA, introduces a mathematical concept of availability[3] defined by the formula:

$$A = \frac{T}{T + D} \qquad (1)$$

where A = availability
T = mean time between failures (actual or estimated)
D = mean down-time (actual or estimated)

Availability considerations introduce the subject of redundancy. One way to boost a system's availability is to incorporate additional subassemblies into the design. If redundant subassemblies are added, it's possible to get a series of levels of operation depending upon the severity of the failure. Table I illustrates the possible combinations of failure and availability for a simple missile-fire-control system composed of a radar (R), a computer (C) and a launcher (L). In operation the radar is employed 100 percent of the time, the computer 50 percent of the time, and the launcher 25 percent. Therefore the selected system has four radars, two computers and one launcher.

Tall says about Table I, "The formula (1) represents in terms of unit availabilities, the fraction of time that each combination will exist. It is helpful to think of the availabilities as probabilities. From the table, the system will be fully operable 77.4 percent of the time and completely inoperable 1 percent of the time. That's because of the redundancy in the system. We call this functional redundancy—equipment duplication which contributes to the system-capacity as well as reliability—as opposed to space redundancy—duplication intended to increase reliability only."

In missile and aircraft works, the factor **percentage of successful missions** is frequently used as the most significant measure of reliability. Trevor Clark, Westinghouse Air-Arm, builds a case for this concept.[4] "In some applications mean time between failures has little value. We're interested in number of missions completed. It's possible for a MTBF to be infinitely long and still a weapons system might never successfully complete a mission."

Still another factor in evaluating a system is its **relative performance under saturation conditions.** Large computers, for example, which may use only a portion of their circuitry in solving some problems, are more likely to perform the computation for these problems reliably than the computation for a very complex problem that requires all of its computing equipment.

TABLE I
RELATIVE FIREPOWER COMPUTATIONS

Combination	Firepower	Formula	Availability
4-2-1	4	$A_R{}^4A_C{}^2A_L$	0.774
3-2-1	3	$4A_R{}^3(1-A_R)A_C{}^2A_L$	0.163
2-2-1	2	$6A_R{}^2(1-A_R)^2A_C{}^2A_L$	0.013
.	.	.	.
.	.	.	.
.	.	.	.
M-O-1 (5 cases: M-4,3,2,1,0)	0	$(1-A_C)^2A_L$	0.000
M-N-O (15 cases: M-4,3,2,1,0 and N-2,1,0)	0	$1-A_L$	0.010
			1.000

The quantity and variety of spare parts required may have little connection to reliability as once defined, but it has a real meaning in system effectiveness. Another way to look at this same factor is to consider the quantity and variety of spare parts required per unit time. Reducing the number and kinds of spare parts a user has to keep on hand makes the system more valuable to the user and eases the maintenance problem. The big problems with inadequate parts supplies are cannibalization and improvisation.

System operability also influences system effectiveness, but it's practically impossible to put into numerical terms.

Most "reliability" specialists agree that the operator has a definite influence on the life of equipment. Equipment in the hands of a good operator lasts longer. Closely related to this is the number of personnel required to operate a system. In industrial applications as well as military, the trend is toward fewer operators. But this has to be balanced against cost (though frequently in military applications money is no object): several operators may be cheaper than highly complicated, more expensive equipment.

The final element in system effectiveness is test and repair-facility requirements. Both military and industrial users strive to keep these to a minimum, the military because field conditions do not lend themselves to elaborate test and repair facilities, and industry because the initial cost and expense of this facility rises rapidly with its complexity.

MEASURING RELIABILITY

Although the concept of system effectiveness is gaining favor, reliability is still the most widely accepted yardstick of performance. And reliability usually means mean time between failures.

If reliability is defined as the probability that a system will perform satisfactorily over a given period of time, "perform satisfactorily" and "given period of time" must be determined for each application. For example, if no failures occur in a statistically significant number of like systems tested for two hours, the design might be considered 100 percent reliable—if it is to be part of a ballistic missile. But it could not be considered reliable for continuous industrial control.

The "mean time between failures" concept thus becomes a measurable factor common to all possible applications of reliability theory. Each user can relate MTBF to reliability in his own case by comparing it to a period considered practical for that application. (Even in the case of equipment which must operate continuously, some finite, practical period with no failures must be considered 100 percent reliable. Nothing lasts forever.)

A system is only as reliable as the weakest component able to affect performance. Unlike the weakest link in a chain, however, a system component need not break down completely to cause a system failure. A small drift in the value of a single parameter of the component may be enough.

A system "fails" when its output is not within specified limits under the input conditions present. Such specifications can be quite loose or very stringent. A simple sewing machine (system) may not fail if it drops one stitch out of ten per inch. But a complex digital computing system does fail if it drops one pulse out of a million per second.

The only sure way to measure MTBF is by life-

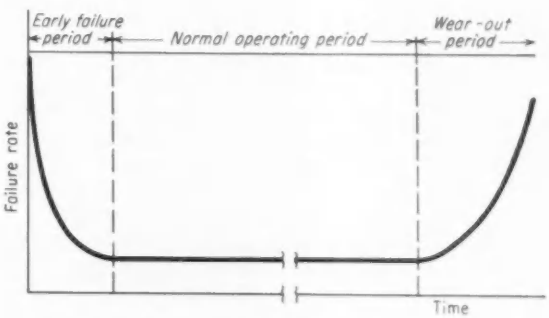

FIG. 1. Assumed normal distribution of failure rates underlying PET concept.

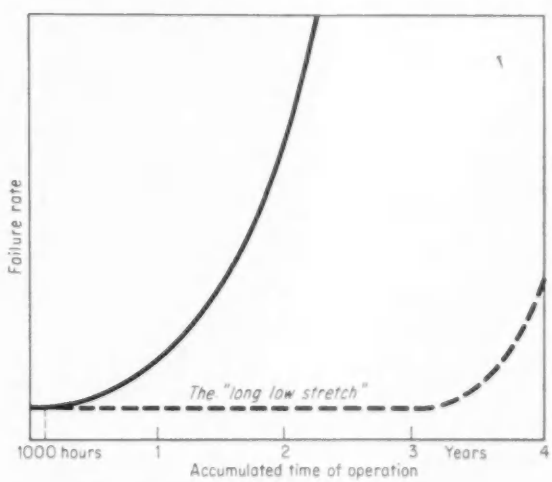

FIG. 2. Lusser's "realistic" failure rate distribution.

testing a large number of items under actual operating conditions. But this is expensive and takes a prohibitively long time; several substitute methods have been developed. Typical of these: 1) production environmental testing, 2) accelerated life testing, and 3) continuous system design tests.

Production environmental testing (PET) involves running for a short period all components and subassemblies through conditions of application similar to those encountered by the completed gear. It is based on an assumption of high infant mortality, as pictured in Figure 1. During PET, weak components fail, so that only selected components are used in final systems. And the "long low stretch" of normal operating period makes measurement of reliability possible.

Today, PET is a controversial subject. On one hand, the data prepared by England's R. Brewer (see page 110) tends to substantiate the high infant mortality premise. But on the other, at least one American, Robert Lusser of Redstone Arsenal, argues for discontinuing PET.[5] Lusser says it is based on an incorrect assumption. He adds, "In mechanical and electronic equipment nothing of that sort happens [referring to an analogy to human statistics]. 'Birth' consists of a mere switching-on, lacking any violence or trauma; nothing 'grows'; no basic changes occur that cannot be determined during the prototype phase; and, in contrast to human beings, components can be and actually are inspected and checked out prior to birth."

Lusser also argues against the theory behind the "long low stretch" of normal operating period. Instead he sees the solid line of Figure 2 as the realistic model distribution. From this curve, he concludes that PET will not increase reliability but may even decrease it. He explains, "If sensitive devices are tested severely and/or for a long time they may easily yield to fatigue, or wear out and fail prematurely in service."

More and more reliability people are looking at accelerated life testing. One engineer calculated that a product would require 33 million unit-hours of test before its first failure, to carry a 99-percent guarantee of meeting an Air Force requirement of 0.014 percent per 1,000 hours.

Still in its infancy, accelerated life testing involves subjecting components or subassemblies to conditions more severe than those to be encountered for a period calculated to be equivalent to normal life at normal conditions of operation.

Typical of an accelerated life testing program is the one at the Sprague Electric Co. and reported by Bernard Hecht.[6] In this progam, capacitor samples drawn from production over a period of four years were subjected to voltages of 140 percent of rated voltage. The failure data was then incorporated into Marcus Acheson's formula for predicting life:

$$S_o = \frac{nt}{NTm}\left[\frac{1-\left(\frac{nt}{nt+NTm}\right)^{r+1}}{r+1}\right]$$

where S_o = probability of N units operating failure-free in T hours
t = life-test time
n = life-test sample size
r = life-test acceptance number
N = number of units used in system
T = required operating time failure-free
m = life-test acceleration factor

In using this formula, only one assumption is made: the fifth-power voltage rule determines the severity factor. In the fifth-power rule, it is assumed that the longevity varies as the fifth power of the inverse ratio of voltage $L_2/L_1 = (V_1/V_2)^k$ (where k is assumed to equal 5). All other numbers come from actual test results or are arbitrary parameters. Solving for life in this way and plotting the solution results in the curves of Figure 3. The top curve indicates the recommended operating voltage to obtain 0.99 equipment reliability for 500 hours at 125 deg C when using capacitors A.

Such data is valuable to designers, but it has some serious limitations. First, it applies only to a particular component—that made by one manufacturer in a single design—and must be gathered from actual failure data over a period of time. It can be upset

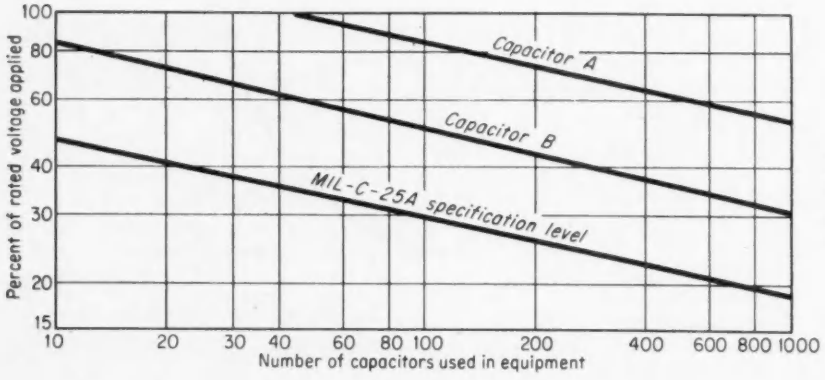

FIG. 3. Recommended operating voltages for metal-clad tubular capacitors for 0.99 equipment reliability based on accelerated life tests.

by a change in design, a new production technique, or failure of quality-control procedures. Secondly, even the manufacturer in this specific example is unable to put confidence limits on the prediction made with these figures. The only way to do so is to compare predicted values vs. actual life values over a long period of time. Finally, there is a question of the validity of the fifth-power voltage rule. Since Marcus Acheson presented a theoretical proof of this rule in 1956 at the Symposium on Quality Control & Reliability in Electronics, little experimental support has been accumulated.

Currently under way at RCA is an Air Force program to develop an accelerated life test for paper capacitors. One part of the program is aimed at checking the validity of the fifth-power rule.

RCA's Joseph Kimmel plots the basic strategy of the program.[7] He says, "A uniformly (constant rate of change) increasing dc voltage is applied to each of two subsamples out of a larger sample drawn from an identifiable universe. The rate of change of voltage, while uniform, is different for each of the subsamples. The test is continued until all specimens fail. Each subgroup is analyzed as an independent sample. Both subgroups are compared for estimation of computational parameters. Subgroups are then lumped for estimation of population parameters."

To analyze the data, this formula has been derived:

$$L = \int_o^t \left(\frac{ct}{V_2}\right)^k dt = \left(\frac{c}{V_2}\right)^k \frac{t^{k+1}}{k+1}$$

where V_2 = any fixed arbitrary voltage, including rated voltage
L = equivalent real life at a constant operating voltage V_2
t = test time to failure
k = a numeric estimated by the test
c = a constant evaluated for each product

This equation makes it possible to convert each test data time t into an equivalent real life time L. However, it's based on knowing k. Since the estimate of mean life is critically affected by k, it is urgent that this variable be evaluated.

At the same time, Kimmel casts a shadow on accelerated life testing by commenting: "There is no assurance that the test truly duplicates normal failure pattern. Conceivably, it forces a novel failure pattern, convertible to the exponential but nevertheless unrelated to real life. Only correlation with real life can remove this doubt."

Still another effort to measure reliability is in what might be termed continuous system design tests. E. J. Nucci describes the program conducted by the U.S. Navy's Bureau of Ships. According to Nucci, a completed system is run continuously under actual operating conditions for 15 (formerly 21) days. Weak circuits, improper use of components, and inadequate components are detected and changed in future designs.

Bu-Ship's program, says Nucci, has several steps. First the 15-day test is applied to the design prototype. Fallible circuit design and component selection discovered during the test are corrected in a pilot-production model. Then pilot-production models are subjected to another 15-day environmental operation test. Again, weak circuits are noted; poor component performance is reported. These changes are incorporated into a production design. As a final check, production model samples, too, are subjected to a 15-day continuous test.

As Nucci points out, by the time all these tests have been completed testers should have weeded out all weaknesses. And they should have a good idea of the reliability to be expected.

This approach appears to have considerable merit where the requirement is for a high-reliability design in production equipment. But it does not help in measuring the reliability of one-of-a-kind equipment, like the SAGE computers for air defense. In such cases, reliability prediction appears the best tool.

RELIABILITY PREDICTION

If it is to be predictable, system reliability must be related directly to the probability of component parameters drifting out of tolerance as well as to the probability of sudden component failures.

To accurately predict the reliability of a system, the MTBF concept must include as a component failure the drift of any significant component parameter beyond certain limits. These limits will vary widely, depending on the circuit or subsystem in which the component is used, and, in general, cannot be stated as a property of the component by its manufacturer in the same way as can the probable time to breakdown or "end of life"—the usually understood meaning of component reliability. The probability of any parameter of a component remaining within specified limits under specified operating conditions throughout its probable lifetime can be predicted, however, by the same statistical measurement techniques by which probable lifetime is determined. This data is very important if systems are to be predictably reliable.

The important causes of parameter drift in a component during its lifetime are:

- Aging (for example, the binder in a composition carbon resistor usually decomposes with age and drying temperatures to form more carbon, thereby reducing the original resistance).
- Environment (small amounts of moisture, sealed in or leaking into the can of an hermetically-sealed transistor, gradually cause its floating emitter potential and collector current to increase. This was explained by R. M. Ryder of

Bell Telephone Laboratories as due to a decreasing surface conductivity shorting the bulk conductivity of the transistor).[8]

Such drift characteristics are predictable only if operating conditions and environment can be considered constant over the lifetime of the component. Specific ways to control parameter drift are:

- Derating (operating components well below manufacturer's ratings).
- Controlling environment (hermetic sealing, for instance; although this may be only partial if the component is also temperature-sensitive).

Having determined the probable parameter-drift characteristics of his components over their lifetimes, the designer must then use them only in circuits or subsystems that can tolerate these expected drifts without producing a system output outside of specified limits—i.e., a system failure. Techniques for predicting the probable variation in system output due to varying component values or tolerances are new and poorly understood.

Product-rule method

A review of current practices for determining system reliability, says the Military Electronic Systems Committee of EIA, reveals the "product rule" method to be the most used, "including the much-too-popular method of predicting system failures on the basis of previously obtained parts failure information". In the product rule method, the system reliability is simply the product of the parts' reliabilities. The method assumes that a part failure is synonymous with a system failure, and also that all parts failures are independent of each other. Its value lies in its very simplicity.

Unfortunately, it is usually applied without consideration for environment or the effect of the tolerance of the circuit on the reliability of the components. However, part failure rates measured in circuits of the kind for which reliability is to be predicted, can yield much better system reliability prediction from the simple product rule.

Propagation of error

A practical attack on how parts characteristics combine to give system characteristics is described by Morreale, Noel, and Potter of IBM Poughkeepsie.[9] They use the "propagation of error formula"

$$\sigma_y^2 = (\partial y/\partial x_1)^2(\sigma_{x1})^2 + (\partial y/\partial x_2)^2(\sigma_{x2})^2 + \cdots + (\partial y/\partial x_n)^2(\sigma_{xn})^2$$

to predict the effect of component tolerances on system error. This formula says that the square of the deviation (statistical) in system output is the sum of the squares of the independent deviations in component values. It assumes that all deviations are small and that component deviations are independent, so that high-order and cross-product terms can both be neglected.

The results of a static (dc) analysis of a single-shot flip-flop having 20 components was used to illustrate the success of this approach. If the tolerances were treated as cumulative, the combined tolerance of the timing of the circuit for 1-percent components would be plus or minus 30 percent. The propagation-of-error formula, however, yields plus or minus 5 percent as the system tolerance for 1-percent components, and only plus or minus 7.5 percent for plus or minus 5-percent components. After these calculations were made, ten circuits were built from components selected randomly from lots of 5-percent components, and the timing of all ten circuits was measured to be within 5 percent of specification.

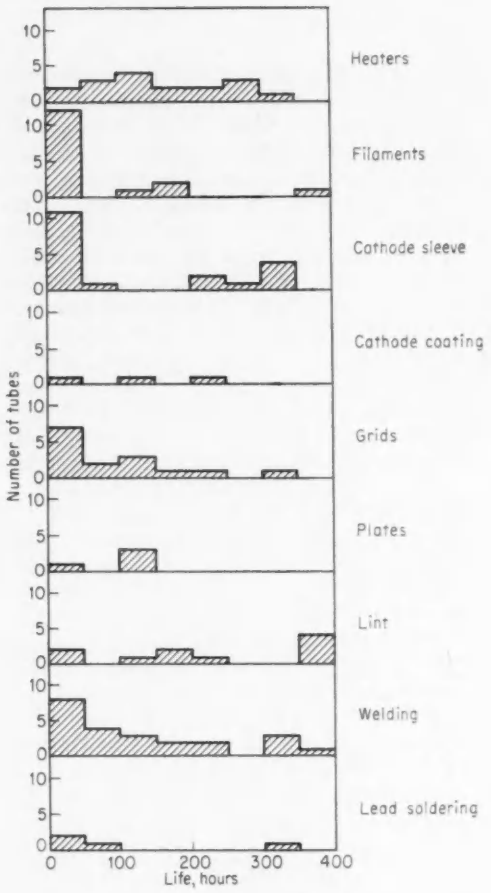

FIG. 4 Analysis of 874 "early failure" tubes (see Figure 1) showed this distribution of assembly faults.

Three-dimensional space

Another technique, described by Robert Glaser of General Electric,[10] uses the experimental designs developed by George Box of Princeton to develop the boundaries of a three-dimensional "space", measured by input variables (such as voltage, ambient temperature, and power dissipation) within which the probability is less than some given amount that a particular component parameter will exceed

a specified variation. It thus becomes possible to predict, from component measurements alone, the reliability of the component under any circuit (or system) conditions which can be described beforehand. A hooker is that such "probability spaces" (our term—Ed.) also vary with time as the component deteriorates, and there still may be other "input variables" to consider. These factors add fourth or fifth dimensions to the "probability space". The resulting families of spaces would have to be searched for the one in which the probability space contracts enough to meet one or more of the circuit operating values for the input variables. This would be the probable "end of life" of the component for the application given.

The "Box technique" really puts statistical mathematics to work, and requires a large number of experimental measurements on each parameter for which a "probability space" is to be developed. Once available, however, such spaces would permit system designers to evaluate components directly for each application rather than by measuring performance in a large-enough sample of systems.

Predictable systems

Such an approach would yield better end-of-life values for the "predictable systems performance" (PSP) design approach developed at Lincoln Laboratories and described by W. J. Canty.[11] This approach requires

> "Test measurements [on the system] to prove that, with one component at its end-of-life value as specified in the component specification, and all other components at their worst initial purchase specification value, the system must work with a perceptible margin [at a marginal check input]. These must be repeated for each and every component at its end-of-life value and all others at their worst initial purchase specification. This procedure makes a good approximation to random deterioration of components available to the circuit designers. The tests must be performed with input signals at their worst value within the specification and with the output load arranged to degrade the circuit operation as much as possible within the output load specifications."

These tests are supplemented during system operation by systematic "marginal test" procedures, which in turn are based on tests at the circuit design stage. This stage must

> "prove that the marginal checking procedures will show significant deterioration of each component. Or, to put it another way, it must be evident that a change in a component which will affect the operation of this circuit will be detected by the marginal input. The . . . variation required at any time on this marginal checking [input] is the 'margin' on this [system]. Changes in the operating margins will be expected as the characteristics of components . . . change."

The PSP technique was used in the design of the various circuits and subsystems of the AN/FSQ-7 (SAGE) air-defense electronic computer. Canty quotes failure rates and numbers for the various components of a 16,000-tube (about 23,000 cathodes) section of the computer measured over 4,466 hours of operation between October and May 1956. The average time to failure of a tube in any one location (assuming a linear failure rate is applicable) in this area of the computer turned out to be 250,000 hours, and the average TBF of a high-speed flip-flop circuit containing about 30 components (including two tubes) was over 100,000 hours. In spite of this, the MTBF for a 10,000-tube portion of the computer in a one-month 15-hour-a-day test was only 7.2 hours. These reliability figures seem much better when it is realized that a very large commercial computer like the IBM 704 contains only 3,700 tubes. The complete SAGE computer is a duplex machine containing about 50,000 tubes. The figures quoted above are for less than half of the SAGE and the MTBF decreases as the active components increase.[12]

Marginal testing can be considered a first-order predictor of imminent component failure, for its use with scheduled maintenance has been proved to greatly increase the MTBF. Similarly, a record of component margins made during routine margin testing can yield rates of change of margins, which would be a second-order predictor that might further increase the MTBF.

Predictions vs. actual reliability

The value and also the limitations of reliability prediction were illustrated by the EIA committee by applying a refined version of the product rule to a radar-computer system. The ratio of predicted to measured MTBF is shown in Table II.

A cursory analysis revealed that the major discrepancy in the radar prediction was due largely to inadequate data on mechanical failures. The prediction technique used and the data available gave an overly optimistic view of reliability. A little feedback would help in future applications.

Reliability tests and component design

Reliability tests can (and should be) designed to turn up the weaknesses in components. In this connection, R. Brewer of the General Electric Co., Ltd. of England,[13] described an analysis of 874 failed tubes which indicated that the major contributions to failure are the cathode or filament

TABLE II
RATIO OF PREDICTED TO MEASURED MTBF

Overall system	1.92
Subsystems	
Computer	0.98
Radar data presentation system	1.08
Radar	5.10

assembly, grid mounting, and welding in general (Figure 4 shows the distribution of assembly faults), with a generous assist from glass treatment in the processing area. Such tests obviously yield some very specific clues about where to start to improve reliability.

MAINTAINABILITY

It is impossible to divorce maintenance from any discussion of reliability. Certainly the quality of maintenance has considerable influence on the effectiveness of equipment. There seems to be no easy answer to the maintainability problem—and only one on which all specialists concur: maintainability must be considered during each phase of development, design, testing, production, packaging, and installation.

A. T. Pollock of Philco Corp. lists four considerations directly related to maintainability:[14]

1. Environmental considerations — How known conditions will affect maintainability (arctic freezing versus tropical humidity, for example).

2. Operational conditions—How system function, complexity and use will affect maintainability.

3. Design-complexity considerations—How peculiarities of design will affect maintainability.

4. Uncontrollable considerations—How abnormal use might affect maintainability.

Environmental and operational requirements are usually spelled out in detail in advance of design. In studying such considerations, says Pollock, engineering effort is generally concerned with systems engineering, system configuration, and unit function.

Improvement of maintainability is important to both industry and the military. One estimate puts the cost of maintaining equipment of standard design over its life at from 10 to 100 times the initial cost. This explains why most users are willing to pay more initially for a design that promises an appreciable maintenance saving (see page 73).

THE ECONOMICS OF SYSTEM EFFECTIVENESS

There is no question but that redundancy adds to the cost of a design, that superreliable components are more expensive than standard ones, that engineering for reliability adds to the final bill. The problem is determining how much the user can afford to pay for how much additional system effectiveness.

It is quite difficult to obtain cost-figures on an improved design. At best, only bits and pieces can be assimilated. Occasionally, however, it is possible to pin down just how much an added effort cost. George A. Raymond, Remington-Rand Univac, reports on development of a computer for the Titan ICBM[15], a development in which reliability was a prime factor. The computer contained 10,000 transistors, 30,000 diodes, 40,000 resistors, and numerous other electronic components for a total of nearly 100,000 electronic parts. And the system was to have a MTBF of 60 hours.

To improve the reliability of components, Rem-Rand requested suppliers to subject semiconductor devices to a special screening before shipment. By applying tighter specifications to these components, the cost, of course, was increased. Raymond illustrated how much with these figures:

Component	Standard price	Cost with added selection
Transistor A	$4.00	$11.50
Transistor B	4.00	10.65
Germanium diode	1.20	2.10

Raymond says that the added selection improved "reliability" about ten times at a cost of less than three times. (In January he said that the computer had been running 40 hours per week since October without a single failure.)

This illustrates one point: The stakes are high in reliability; from an economic standpoint, it is unsound to spend too much or too little to increase system effectiveness.

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MASS SPECTROMETRY in Process Control

THE GIST: The mass spectrometer's outstanding advantages of speed, versatility, and ability to resolve multicomponent samples have resulted in many successful applications in plants and laboratories. Since 1942 the instrument has been used in laboratory analyses of batch samples of chemical and petroleum streams to help determine process-controller set-points. Lately, however, there has been a trend toward direct mass spectrometric control of continuous processes.

The table in this article describes some of the features of mass spectrometers and lists some of the applications reported so far. Further use of mass spectrometry in process control may be expected as experience accumulates and as instruments and related computing equipment are improved and reduced in cost.

ROBERT WALL, Monsanto Chemical Co.

The information provided by an analytical mass spectrometer is known as a mass spectrum, a plot of ion abundance vs. mass number. The spectrum results from two basic functions within the spectrometer: ionization—the fragmentation of molecules in a sample into ion masses; and mass analysis—the separation of the ion masses into individual M/Q (mass per unit charge) groups and the measurement of the ion abundance in each group.

In general, every molecular species in the sample ionizes to all its possible single-charged masses and to some multiple-charged masses. For constant conditions and for the relatively large number of ionizations per second, the mass numbers (M/Q) and the relative abundance of ions produced for each molecular species are precise and characteristic for that particular species. Figures 1A, 1B, and 1C show portions of mass spectra for samples of pure n-butane, isobutane, and propane. N-butane and isobutane molecules have the same mass numbers but different ion-abundancy distribution.

The mass spectrum of a compound sample, made up of a number of different molecular species, exhibits all mass numbers found in the spectra of the individual components (species); the ion abundance at each mass number is the sum of the ion abundance contributed by each species. Figure 1D synthesizes the mass spectrum that would be obtained for a sample containing equal amounts of the components shown in Figures 1A, 1B, and 1C.

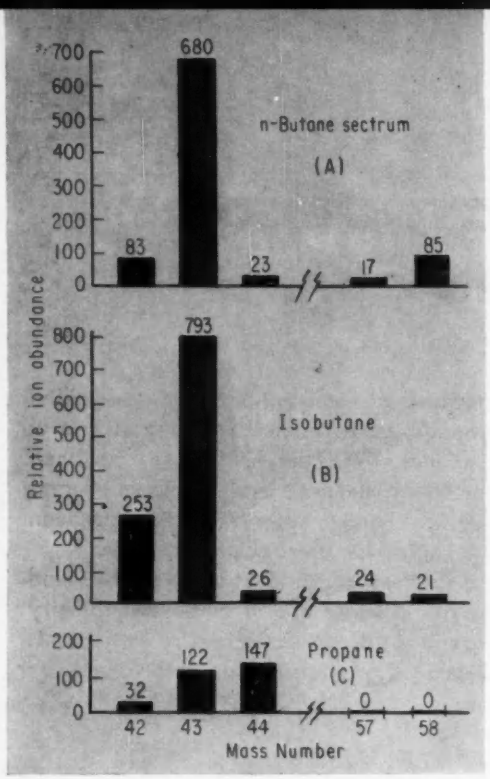
The composite spectrum of Figure 1D is an extremely simplified version of spectra actually obtained with mass spectrometers. In industries dealing with hydrocarbon mixtures, for instance, the spectrum may include over 100 mass numbers, due to fragmentation of the 15 or 20 components in the sample. The mass spectrometer yields information about the ions in a compound sample, but not about the molecular components present or their relative concentrations. The latter requires solution of a set of simultaneous linear algebraic equations. For simple samples, the solution can be manual; complex ones need a computer.

Ionization

In ionization, sufficient energy to remove an electron (or electrons) or to break a molecular bond (or bonds) must be transferred to a molecule. Mass spectrometers for analyzing petroleum and chemical streams utilize electron bombardment exclusively. A sample, in the vapor phase at low pressure, is bombarded by an electron beam of definite selected energy. A small fraction of the electrons collides with, and ionizes, molecules of the sample.

Figure 2, a diagram of the 180-deg spectrometer, shows the relationship of the ion source to the other major parts (the mass analyzer, the collector-readout system, and the vacuum system) of the instrument. The ion source is the dominant part of the mass spectrometer. It is complex and involves many interrelated functions, so that it almost completely determines the spectrometer's accuracy and operational characteristics.

Ion beam formation requires a sampling system, an electron gun, and a set of accelerating electrodes. The sampling system sends a representative sample flowing through the ionizing region and maintains the proper pressure in that region. Figure 2 also shows two sampling systems; one, for laboratory analyzes, uses a reservoir admitting a measured pres-



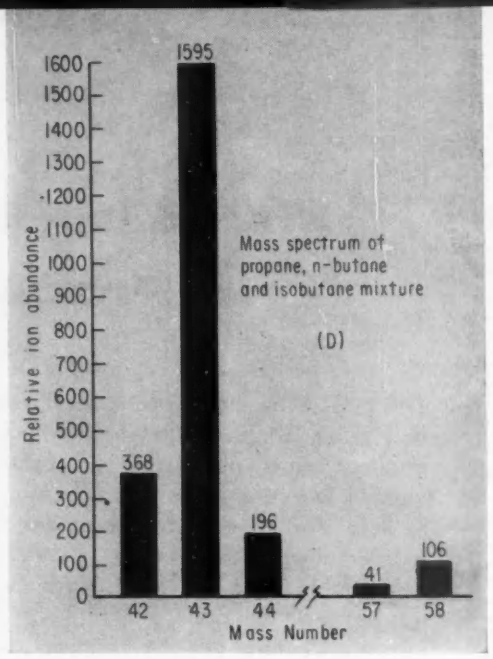


FIG. 1. Mass spectra of pure propane, n-butane, and isobutane, and the resulting spectrum obtained from a mixture of equal amounts of these components.

sure of sample; the other, for continuous analysis of process streams, uses a capillary bleed system.

The electron gun accelerates electrons emitted thermionically from a tungsten filament through a system of aperture electrodes, to form a tight collimated beam through the ionizing chamber. The electrons are held in this beam by a focusing magnetic field in the source. The intensity of the ion beam will be directly proportional to the ionizing electron current, and its controlled constancy will determine the accuracy of a quantitative analysis.

Once the electron beam has ionized the sample, an electric field repels the ions from the ionizing chamber into the ion-accelerating region of the source. , Shaped electrodes, having appropriate potentials applied to them, comprise the ion gun. The gun accelerates the ions and forms them into another collimated beam, which passes through the source exit slits into the mass analyzer section. This arrangement efficiently utilizes the ions by applying the principles of electron optics—which also hold for ion optics—in forming an ion beam having a small angular divergence as it enters the analyzer.

The formation of ion beams of adequate intensity for accurate measurement and high sensitivity requires a relatively large amount of sample molecules, hence a comparatively high pressure, in the ionizing source. However, the pressure must be small enough to prevent collisions between molecules and ions, and attendant production of secondary ions. This requires a mean free path (distance between collisions) much greater than the dimensions of the ionizing chamber. When this requirement is met, the desired condition of molecular flow has been achieved. Typical pressures in the ionizing region are about 10^{-4} mm Hg.

Mass analysis

Once the ions are formed they must be sorted into their individual M/Q groups and the quantity in each group measured. In the electromagnetic mass spectrometer a geometric separation, due to the fact that the ion paths differ for each M/Q for a particular preferred arrangement of electric and magnetic fields, sends only the selected M/Q through the exit slit to the collector plate. The collector current required to neutralize the ions falling on the collector is quantitatively measured by a conventional feedback electrometer amplifier. Electrometer design is well developed and the operation of the various models highly reliable and accurate. The measured currents vary from a detection limit of about 10^{-14} amp to a maximum of about 10^{-10} amp. Recording by either oscillograph or pen is almost always used, and frequently the spectrum data is simultaneously converted to digital form for interpretation by a computer. The arrangement is shown at the lower right of Figure 2.

Figure 3 shows in detail the paths taken by the ion groups in the beam for the 180-deg analyzer. The entering ion beam has been accelerated through an electric-field potential E_A in the source, and is under the influence of a magnetic field. As a result, each ion group follows a circular path described by the useful mass spectrometer equation:

$$BR = \sqrt{2E_AM/Q} = 144\sqrt{E_AM}$$

where Q is unit charge, M is mass units, B is mag-

netic field in gausses, R is radius of ion path in cm, and E_A is the potential in volts.

Conventionally, the mass spectrum is scanned by gradually varying the ion-beam accelerating voltage or by varying the strength of the magnetic field. In either method the different M/Q's comprising the entering beam are swept in sequence across the exit slit of the analyzer. A particular voltage corresponds to a particular mass number, and a record of ion abundance (collector current) vs. mass number is the mass spectrum of the sample from which the subsequent analysis is interpreted.

The ion source itself consists of a multiple-slit system, as seen at the left of Figures 2 and 3. Ions accelerated into the mass analyzer section enter with slightly divergent entrance angles, α. The different entrance angles cause a displacement of the center of curvature. The spread S of the ion beam equals $R\alpha^2$ to a first approximation when α is small. The ion paths diverge to 90 deg, and then converge to an approximate focus at 180 deg, at which point the beam falls through the exit slit and hits the collector plate. The spread of energy ΔE_A of the entering ions causes a change in radius R.

Resolution M/dM of the mass spectrometer is the instrument's ability to separate mass M from adjacent mass $M + 1$. Resolution can be stated by:

$$M/dM = R/(S_1 + S_2)$$

where S_1 and S_2 are the entrance and exit slit widths, and $R\alpha^2$ is negligible. The significance of the ion-beam spread on resolution may be considered by comparing $R\alpha^2$ with $(S_1 + S_2)$.

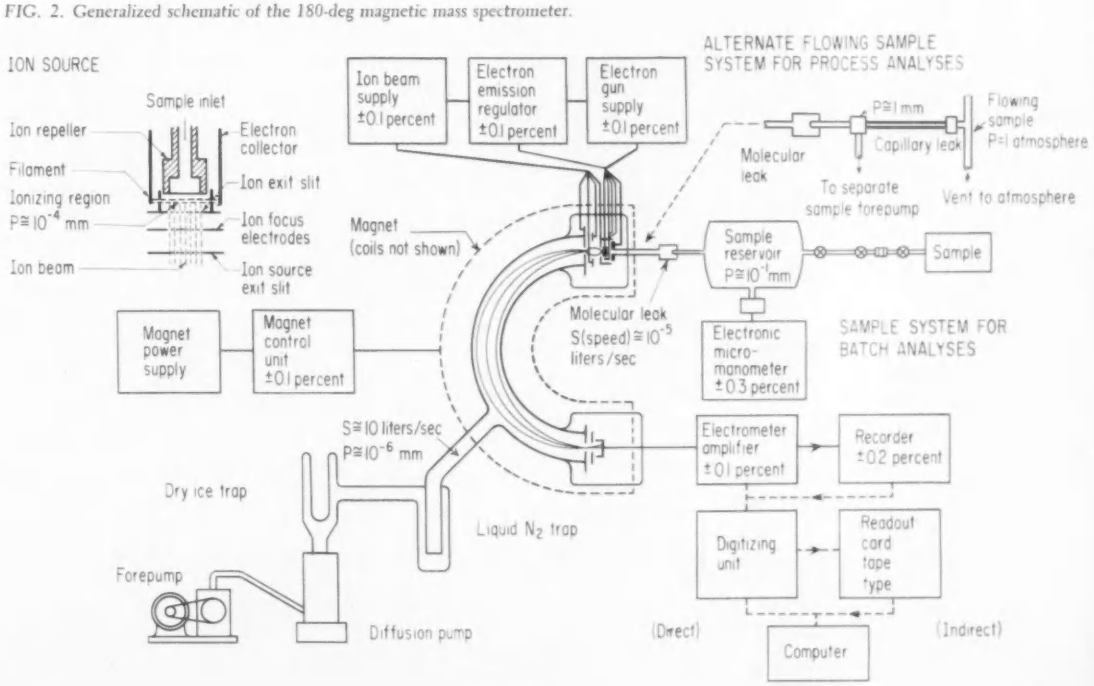
Ion-beam dispersion can also be caused by ions in the beam colliding with residual gas molecules in the analyzer. To avoid this, the pressure in the mass analyzer is kept low. It must be much smaller than the pressure in the ion source because of the size of the analyzer ion path, about 50 times greater than the source dimension. The high pressure in the ion source and low pressure in the analyzer can be maintained by differential pumping (a typical mass analyzer pressure: about 10^{-6} mm Hg.)

The pressures in the source and analyzer sections vary inversely as the rates of molecular flow from source to tube envelope to vacuum system. In practice differential pressure ratios as high as 30 to 1 are obtained. The vacuum system maintains the pressure throughout the instrument low enough to make ion-molecule collisions infrequent, and the background spectrum produced by action of the ionizing electrons on the residual gas unimportant compared with the ion density resulting from a normal sample.

The 180-deg mass spectrometer predominates for quantitative analysis applications. A variation of the electromagnetic analyzer is the sector-type mass spectrometer. In theory, the sector angle can be between zero and 180 deg and the entrance and exit arms do not have to be symmetrical; in practice, however, these analyzers have had sector angles of 60 and 90 deg, and their arms have been symmetrical. The general condition for sector instruments is that the entrance and exit slits and the center of curvature of the ion path lie in the same straight line.

Another variation of the electromagnetic analyzer is the crossed field or cycloidal mass spectrometer. This analyzer is unique in that ions entering the analyzer section with any initial energy and at any direction are focused perfectly on the exit slit. The

FIG. 2. Generalized schematic of the 180-deg magnetic mass spectrometer.



WHAT MASS SPECTROMETERS CAN DO

The mass spectrometer can rapidly analyze multicomponent streams, ranging from gases to fairly heavy liquids that have been converted to vapor. It can detect components with concentrations as small as a few parts per million. Frequently, it is the only analysis instrument that can meet the required conditions of speed, precision, and sensitivity for particular applications. The mass spectrometer is a very complex instrument and requires rather exacting conditions for successful use; simpler instruments, however, are being developed.

WHERE MASS SPECTROMETERS HAVE BEEN USED

•monitoring isotope separation units in atomic energy plants
•locating producing zones in oil fields by analyzing drilling muds
•analyzing exhaust gases and fuel-air mixtures for rapid and effective studies of the operation of internal combustion, jet, and gas turbine engines
•controlling underground combustion processes (for recovery of heavy crude oil from spent wells) from the gases produced
•controlling furnace atmosphere in high-vacuum metallurgy
•controlling a process to extract by-product sulfur from natural and refinery gases

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equation of ion-mass motion for this instrument is:

$$b = \frac{2EM}{B^2Q}$$

where b is the slit spacing, E is the electric field, and the other symbols are as previously noted.

Time-of-flight spectrometers

The discussion so far has centered on the electromagnetic mass spectrometer. Another important class of instruments is the time-of-flight mass spectrometer, which uses transit time in an electric field as a function of M/Q to separate ion-mass groups, rather than on the geometric basis associated with the electromagnetic type.

Beckman Instruments markets the rf time-of-flight mass spectrometer shown schematically in Figure 4. Ions formed in the ion chamber are accelerated into the rf analyzer, and then further accelerated through a series of spaced grids to which an rf potential is applied. Only the ion group resonant with the alternating electric field will acquire the maximum energy possible from the linear accelerator. That is, only the ions that travel from grid to grid in exactly the time to receive the maximum acceleration will pass through the exit slit. A kinetic energy selector rejects ions not in resonance, and only the resonant mass reaches the collector for measurement of abundance.

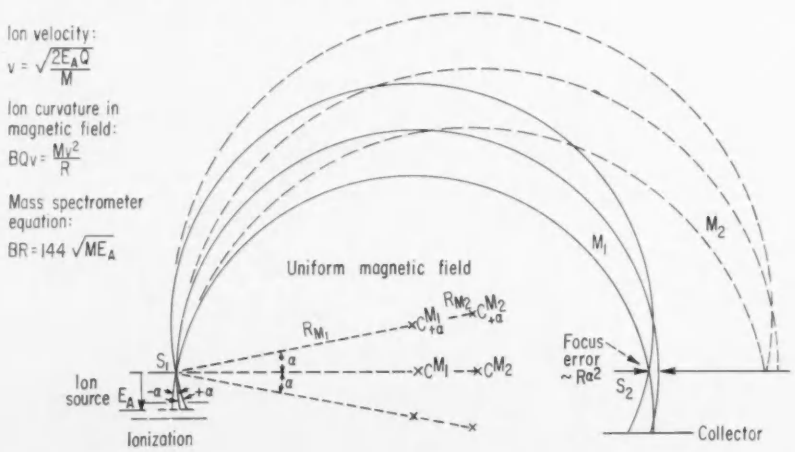
The ion current of the rf mass spectrometer is not limited by the collimating action of beam-forming slits or by the requirement that the beam pass through the narrow analyzer slits. Thus, the beam can be larger in cross-section than in the electromagnetic type. This should result in greater efficiency of utilization of the ions and in relatively large currents at the detector, but it does not, for a variety of reasons; the ion currents actually realized are of the same order of magnitude as those in the magnetic instrument.

Bendix markets a time-of-flight mass spectrometer using pulse techniques. Ions are accelerated by a very brief pulse (microseconds) of applied voltage into a drift path, which they travel at velocities inversely proportional to the square root of ion M/Q's. The ion groups thus separate timewise according to mass, with the lighter ions reaching the collector first. The collector functions as an extremely sensitive ion multiplier. The complete mass spectrum of each pulse is presented oscillographically, often with as many as 10,000 scans per sec. This analyzer is particularly useful for analyzing such phenomena as fast chemical reactions. An integrating collector-readout is available.

Practical considerations

The excellent performance of modern mass spectrometers is the result of years of intensive and considerably empirical development. Analytical accuracy depends on calibration with known samples, while precision depends on maintaining those conditions that make the best compromise between several mutually contradictory requirements. Two such requirements have already been mentioned: relatively high pressure in the ion source to provide high sensitivity, and low pressure in the analyzer section to avoid ion-molecule collisions. A large electron current is desirable for high sensitivity but otherwise undesirable: the negative space charge of the beam perturbs the small ion-accelerating field in the ionization chamber. Some of the ions produced during sample bombardment will appreciably neutralize this negative space charge—if the sample pressure is high enough. Compounds

FIG. 3. Ion trajectories of different masses in a uniform magnetic field.



vary considerably in ion production and have a corresponding effect on the small source field as the space-charge distribution varies with both sample composition and pressure, with a resultant effect on ion-beam intensity.

Filament-conditioning, another practical consideration in the operation of a mass spectrometer, is a technique that is part of the art of mass spectrometry. The tungsten-filament source emits electrons as a surface phenomenon which is markedly affected by interaction with the sample. The interaction causes variations—as the sample varies—in filament temperature, energy of emitted electrons, and beam cross-section density. The filament is conditioned by operating with a large sample of isobutane or similar material for several hours, or until the tungsten is partially carburized and the emission quite stable.

The complexity and maintenance requirements of the modern mass spectrometer have been reduced to the point where many today are adapted to in-plant process applications and require far less attention than those of a few years ago. The instrument has been simplified and improved through clearer understanding of the operating principles, improved components and auxiliary equipment, and better circuits. Modern oil diffusion pumps, operating with baffles and often without charcoal traps, help too.

Interpreting data

The process mass spectrometer is almost always used as an indicator, an operator manually resetting the process controls based on the information it furnishes. Most in-plant applications to-date are characterized by analyses in which unique peaks may be read directly from the chart without the necessity for calculation; in this case, direct control from a mass spectrometer is easily accomplished. Unfortunately, however, there are only a few multicomponent hydrocarbon streams in the petroleum and chemical industries in which mass spectral interferences do not overlap a unique peak. Spectral interferences are the rule, not the exception, and they call for calculations to determine the molecular species and their concentrations in the stream.

Every sample component has a characteristic mass spectrum on the pure component to be determined that can be expressed by:

$$\text{spectrum of } A = P_A [K_{AM} + K_{AM'} + K_{AM''} + \text{— — — —}]$$

where A is the component, P_A is the partial pressure of pure A as measured at the sample entry system, and K_{AM} is a calibration constant characteristic of component A for each M (or M/Q) ion resulting from the ionization of A. Spectra of components B, C, D, etc., can be represented in a similar manner.

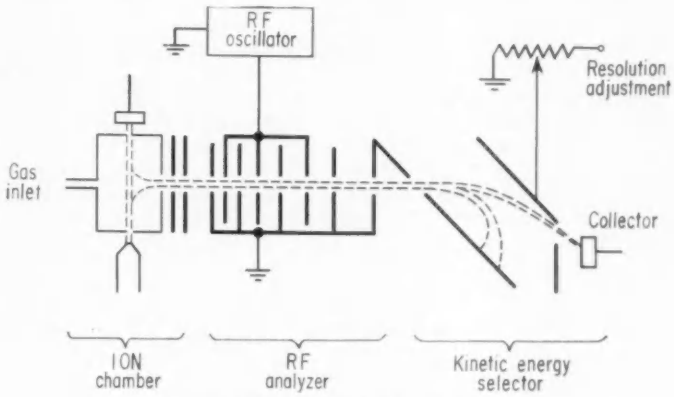


FIG. 4. Generalized schematic of the rf mass spectrometer

The peak height of each mass of the spectrum of a multicomponent sample containing several components is then:

$$H_M = P_A K_{AM} + P_B K_{BM} + P_C K_{CM} + P_D K_{DM} + \text{—}$$
$$H_{M'} = P_A K_{AM'} + P_B K_{BM'} + P_C K_{CM'} + \text{— — — —}$$
$$H_{M''} = P_A K_{AM''} + P_B K_{BM''} + P_C K_{CM''} + \text{— — — —}$$
$$H_{M'''} = P_A K_{AM'''} + P_B K_{BM'''} + \text{— — — — — — — — —}$$

where H_m, $H_{m'}$, etc., are the peak heights of the sample spectrum as read at the respective masses, and: $P_S = P_A + P_B + P_C + P_D + \text{— — —}$ relates the measured sample pressure to the partial pressures of the components. These partial pressures are the unknowns in the matrix of equations set up by reading sample peaks; after they are found they can be normalized to mole-percent concentrations. Note that the foregoing mathematical representation of a composite spectrum is similar to the simple spectrum synthesized in Figure 1.

The simultaneous equations can be solved several ways. If the computation is made with sufficient precision the accuracy of the resulting sample analysis will be limited only by the accuracy of the oiginal data. It takes an experienced person about 15 min to manually solve equations containing only three or four components (the sample may actually contain more components). For 15 to 25 components the manual calculation could take two hours. Such lengths of time are often intolerable for in-plant stream analysis and for repeated laboratory analyses.

Before a sample analysis can be calculated the instrument response to known quantities of each component must be determined. In effect, this means that a pure sample of each of the components (perhaps 20) must be run through the spectrometer to obtain calibrations for them. If a variety of samples are being analyzed and the calibrations vary appreciably with time, more time can be spent calibrating the spectrometer than running useful analyses. As it is, the relative sensitivity and instrument performance are determined periodically, using n-butane or something similar in molecular structure, and the necessary instrument adjustments are made from the resulting readings. Excellent long-

term spectral stabilities are usual for hydrocarbons, but other materials may require more attention.

Once an accurate and stable spectrum is assured, electronic digital computers prove helpful in reducing the time for the solution of the simultaneous equations. An advanced system, the Spectrosadic of Consolidated Electrodynamics Corp., utilizing a direct readout into a digitizing system, has been developed for laboratory use. It is particularly valuable for frequent routine analyses of multicomponent samples of similar composition because it eliminates reading charts and transcribing data.

Monsanto has successfully used mass spectrometers for controlling one of its unit processes at Texas City. The installation of three mass spectrometers and the associated sampling system in the control house is shown in Figure 5. Three are used here because the process is such that continuity of analysis must be assured. If one is taken out of service, two others will be available to take its place. Any one spectrometer can analyze all samples at about 20 sec per point. When two or three spectrometers are available for on-stream duty the sampling system shares its streams to reduce the analysis time.

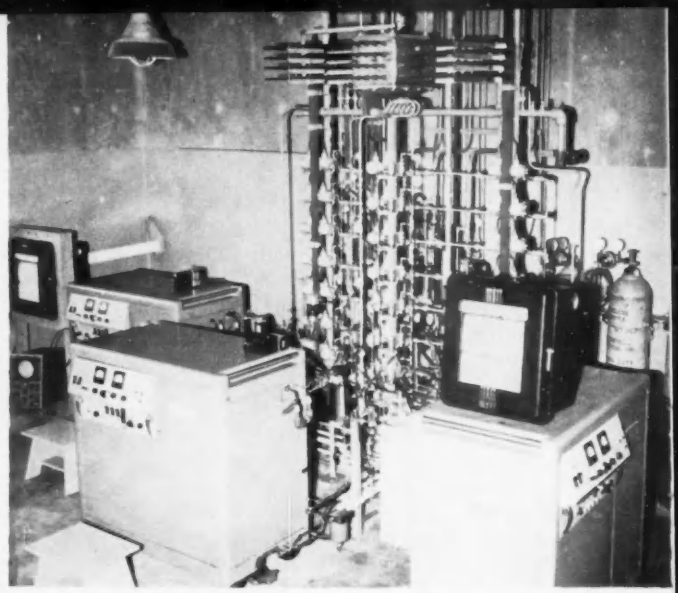


FIG. 5. Mass spectrometer installation at Monsanto plant in Texas City.

What's available

Several mass spectrometers are available for process applications, including Beckman's rf gas analyzer, and Consolidated Electrodynamics Corp.'s recently developed Model 21-611, Figure 6. Other spectrometers for process applications are CEC's Model 21-610 electromagnetic analyzer and Model 21-620 cycloidal analyzer. All are compact and have limited resolution (compared with a laboratory spectrometer) and minimum requirements for utilities services and maintenance. They are adaptable to installation directly at the operating site, and can be used as limited-purpose laboratory instruments.

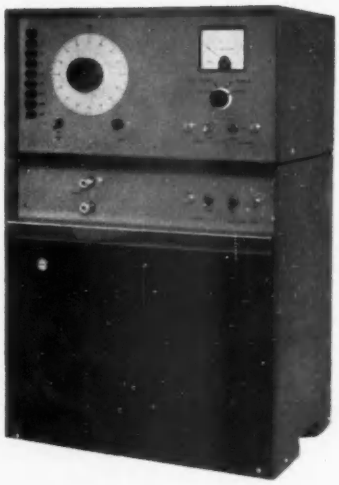


FIG. 6. Consolidated Electrodynamics Corp.'s Model 21-611 mass spectrometer.

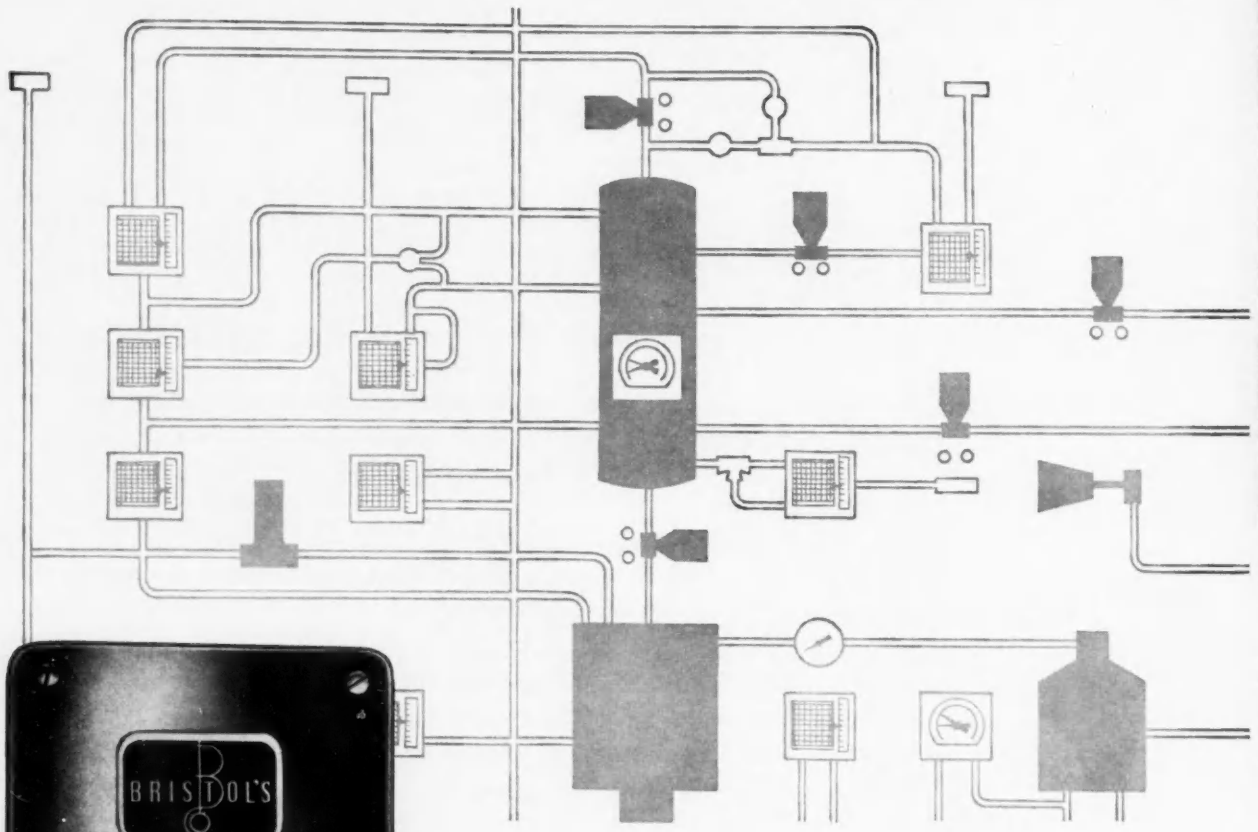
Consolidated's Model 21-611 is the most advanced mass spectrometer for process applications. It has a simple vacuum system operating without traps. Its electronic circuits are highly developed and reduced to essential high-quality components. The instrument is very compact, attractively packaged, and simple to install at an operating process site. Its unitized construction simplifies maintenance. The next stage of development, to an explosion-proof housing, is believed to be in progress.

The most advanced laboratory mass spectrometric system currently available is CEC's combination Model 21-103 and Spectrosadic automatic peak reader. The Spectrosadic converts analog measurements of ion-abundance into digital information ready for interpretation by a computer.

The Consolidated-Nier Model 21-201, a 60-deg sector instrument designed particularly for isotope ratio measurements, is also useful for analytical work within the limits of its mass range and resolution. Its dual collectors receive a pair of adjacent isotopic masses; the two resulting currents are ratioed directly, canceling several sources of error and giving highly accurate ratio measurements.

Several mass spectrometers of specialized design have been marketed for leak detection. These instruments are highly sensitive but of limited versatility: they are focused only for hydrogen or helium. The input to the leak detector is connected to the system being leak-tested, perhaps the housing of an hermetically-sealed gyroscope. Helium is sprayed over the housing surface and the spectrometer observed for any helium within the case.

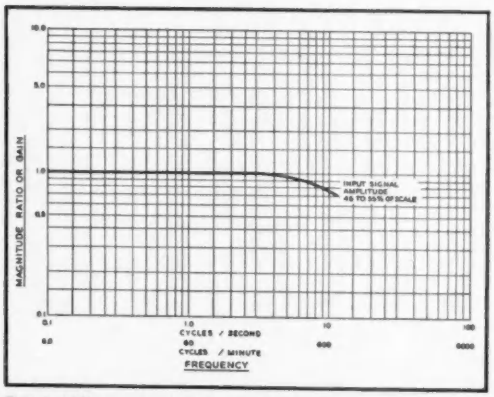
An alternate leak-testing method is to pressurize the inside of the system with helium and explore the outside surface with a probe that sniffs the surrounding atmosphere for evidence of the gas. This method has also proven useful for searching for leaks in hydrocarbon-carrying pipelines, because the mass spectrometer can detect the hydrogen ions resulting from the ionization of escaping materials. Leak detectors were extremely valuable in the construction of the Atomic Energy Commission's Oak Ridge installation.



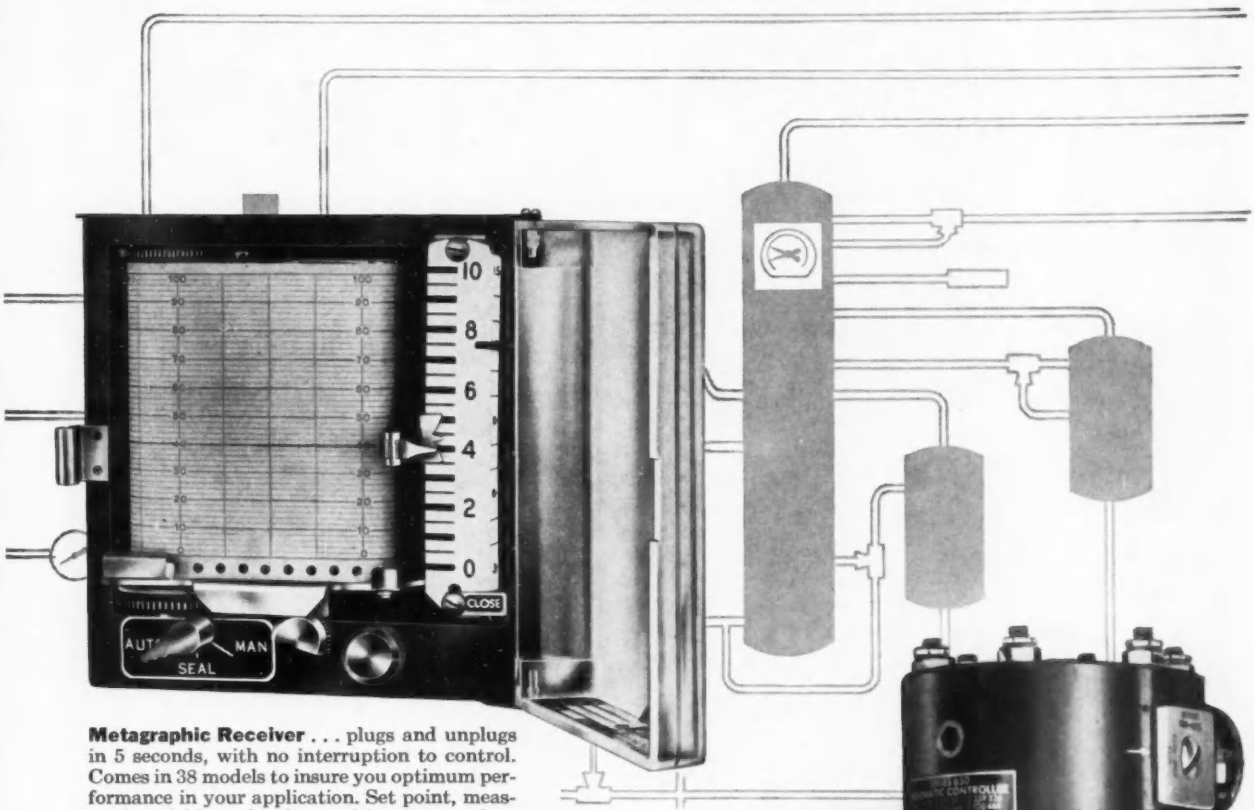
Why Bristol's Metagraphic System

gives you "Hi-Fi"

Metagraphic Transmitter ... offers you the broadest range and widest coverage for measurement of temperature, pressure, vacuum, differential pressure, flow, liquid level or mechanical motion. Standard Bristol measuring elements insure accuracy. 3-15 psi output signal.



Bristol Metagraphic Receiver frequency response is outstanding for a pneumatic instrument. At high end, the 70.7% response point occurs well above 10 cycles per second.



Metagraphic Receiver . . . plugs and unplugs in 5 seconds, with no interruption to control. Comes in 38 models to insure you optimum performance in your application. Set point, measured variable and valve position are continuously indicated on same scale. Indicator models also available.

pneumatic control

Many of the instrument men using the Bristol Metagraphic pneumatic system are hi-fi hobbyists. The term "hi-fi" just naturally comes to mind when they compare the performance of the Bristol Metagraphic with other makes of pneumatic control systems.

The Metagraphic Receiver has, without question, the best frequency response characteristic of any comparable pneumatic receiver on the market. In fact, it's being used as a test standard by one user for response analysis.

And, the matched characteristics of the Metagraphic transmitter and controller insure you optimum process control . . . with minimum lag or other distortion.

If your process needs the best in pneumatic control systems, get complete data on the Bristol Metagraphic. Our engineers will be glad to discuss, in detail, the characteristics of the Metagraphic system and how the system can be adapted to your particular requirements. The Bristol Company, 101 Bristol Road, Waterbury 20, Conn. 8.5

Metagraphic Controller . . . this outstandingly rugged, trouble-free controller supplies precision pneumatic control of almost any variable. Operates from "universal" 3-15 psi pneumatic input signal. Proved force-balance operating principle requires almost no moving parts, nothing to wear out.

BRISTOL *TRAIL-BLAZERS IN PROCESS INSTRUMENTATION*

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CONTROL is first! Now—one step static control with switching reactors

No wonder Nikita looks worried. CONTROL has taken the strain off American industry's pocketbook by cutting the cost of static control.

American engineers who want to make free use of power switching guided by digital logic can now take over, because CONTROL's standard line of switching reactors give freedom of design and economy never before available.

First, one-step static control with switching reactors is so easy to operate it can be put to work in everyday sequencing and switching problems involving either a-c or d-c loads. Auxiliary equipment is eliminated by the basketful. Gone are all the preamplifiers, special power supplies, information-sorting single purpose logic units, and power switching relays. CONTROL's one-step switching reactor does most of the job by itself.

Second, these units, in four nominal volt-ampere ratings of 15, 75, 150 and 300, have no relay contacts or moving parts to replace. Switching is by impedance change. Install them and forget them—no wear, no maintenance.

Third, each CONTROL reactor performs all logic functions —AND, OR, NOT, MEMORY and TIME DELAY—through its multi-purpose control coils. Signal source is derived typically from limit switches, push buttons, or photo-cells.

Fourth, each unit has a 10,000:1 switching ratio under nominal supply voltage conditions. High inrush currents are handled without difficulty.

To learn how CONTROL reactors work, and how they'll fit your need for completely dependable, low-cost, versatile static control, write—and see why Nikita looks worried. *CONTROL, Dept. CE-46, Butler, Pa. U. S. A.*

Reliability begins with CONTROL

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*Expurgated translation. Heavens-to-Betsy!

Using the Acceleration-Switching Valve

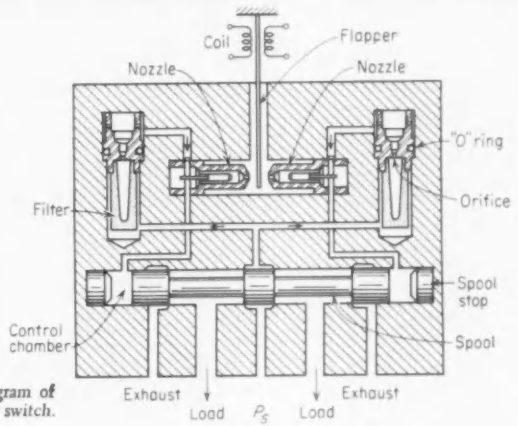


FIG. 1. Schematic diagram of a hydraulic acceleration switch.

W. I. HARRIS
McDonnell Aircraft Corp.

A cross-section view of a typical switching valve is shown in Figure 1. Using the switching technique, the torque motor flapper is driven from nozzle to nozzle by a square wave whose amplitude is high enough to cap off the nozzles completely for approximately one-half of each cycle. If the square wave is perfectly symmetrical there is no average force tending to push the spool in one direction or the other. If it is not perfectly symmetrical, one nozzle will be capped off longer than the other and the resulting net force will push the spool toward one of the stops (see Chubbuck[1]).

Since the spool is not restrained by springs as it is in conventional "linear" valves, the spool position theoretically is proportional to the time integral of the square-wave unbalance. Then, since in addition the position of the piston in an actuator is proportional to the time integral of the oil flow into the actuator, it was assumed that a switching valve, in combination with an actuator, would act as a double integrator.

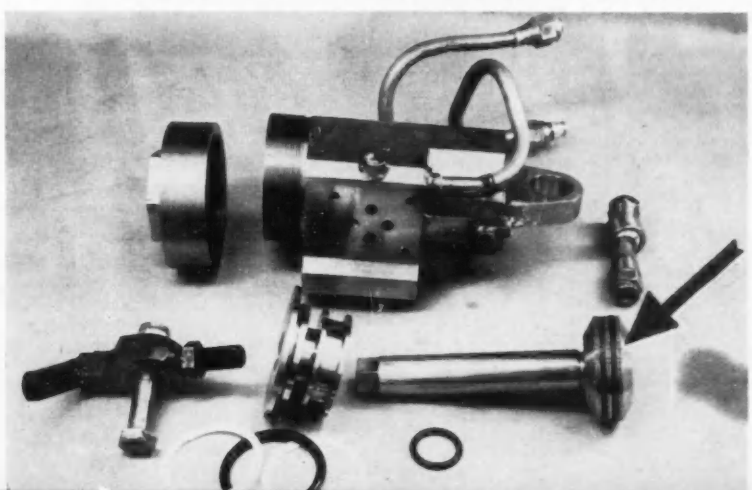
Experiments have shown that the acceleration-switching valve does not perform as a pure integrator. Rather, the transfer function of the valve has the form:

$$G(s) = \frac{K\tau}{1 + \tau s}$$

where τ typically has a value between 0.1 and 1.0 sec, and in general the time constant decreases as the rated flow of the valve is made larger. For example, a switching valve with a rated flow of 1.8 gpm, with 933 psi across the valve, has a time constant of 0.14 sec, and another valve with a rated flow of 0.33 gpm at 933 psi has a time constant of 0.38 sec.

Valve manufacturers are rating switching valves in terms of a so-called "acceleration gain" with units of in.^{3} per sec^2. This rating may be used for the value of K in the transfer function of the valve, but it is important to remember that the K must be multiplied by the valve time-constant to obtain the proper gain for servo design. The "acceleration gain" is derived by the manufacturer by multiplying the valve-spool velocity by the spool-orifice gain (which would be the correct valve gain only if the valve were actually a true integrator).

FIG. 2. Notice wear on piston of actuator subjected to side loading at high temperatures. Abraded material contaminates oil and clogs valves.



To-date, the hoped-for economies have not been realized in servos using switching valves. The switching valves themselves cost at present as much or slightly more than linear transfer valves, and most manufacturers (those who would use the same equipment and procedures to make both valves) deny that the savings promised by the switching valve's relaxed tolerances will ever be significant. In addition, the switching technique does nothing to reduce the required manufacturing precision (hence cost) of the servo actuator and linkages.

ASV is more reliable

Perhaps the most promising feature of the switching technique is increased reliability under adverse environmental and operating conditions. Oil temperatures in many guided-missile applications, have become very high. All conventional linear valves tested to-date have exhibited a large null shift, of the order of 15 percent or more, when the oil temperature is raised from room temperature to 400 deg F. The temperature sensitivity of the switching valve, however, is considerably less, because the null is determined primarily by the symmetry of the input square wave. The high spool-force level in the switching valve is certainly a help in preventing jamming by particles in the oil due to component wear.

Recent tests of ASV-servos at high temperatures tend to confirm these reliability advantages. Figure 2 shows the extensive disintegration of an actuator subjected to side loading in high temperature tests. The servo operated for several hours before the actuator froze. But the operation was imperfect because the null shifted as a function of frequency. This was probably caused by substantial clogging of one of the upstream orifices, which would make the spool velocity appreciably greater in one direction

than the other. It is difficult to imagine worse operating conditions. (Note that the upstream orifices in the switching valve are typically 0.003 to 0.005 in. in diameter, as compared to 0.0006 to 0.0008 in. in the flapper-nozzle circuit of conventional valves; the latter obviously would clog more readily. And a null shift of this type is not a catastrophic failure.

In other tests under the same high temperatures (oil temperature 275 deg F, ambient 500 deg F), switching valves were operated for periods of several hours without any noticeable performance degradation.

REFERENCE

1. *ARE HIGH PERFORMANCE AND LOW COST COMPATIBLE IN HYDRAULIC SERVOS?* J. G. Chubbuck, "Control Engineering", March 1957, p. 98.

Bremsstrahlung Gages Improve Thickness Control

N. A. HART
Baldwin Instrument Co., Ltd.
England

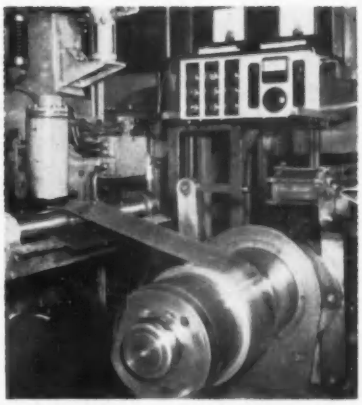


FIG. 1 Bremsstrahlung measuring head is small; can be located closer to rolls on strip mill, to reduce transportation lag and improve control.

Bremsstrahlung radiation – x-rays emitted when a metal target is bombarded by beta rays–offers certain advantages over conventionally produced x-rays or beta rays for gaging thickness of metal strips in rolling mills. Radiation gages using the Bremsstrahlung effect have thickness ranges significantly greater (0.004 to 0.040 in.) than nucleonic gages (limited to less than 0.020 in.) using beta rays directly, and avoid the high cost, fragility, and bulkiness of x-ray tubes.

Figure 1 shows a Bremsstrahlung radiation gage installed on a four-high rolling mill that will accept brass strip between 0.007 and 0.030 in. and deliver a finished gauge of 0.005 in. Only the detector assembly can be seen. The beta source (strontium 90) is located in a shielded container below the strip, Figure 2, and bombards a metal target in the source container, which in turn emits the radiation.

The target emission is directed through the strip to the detector by a solenoid-actuated shutter with three apertures. The radiation that penetrates the strip strikes a sodium iodide crystal which "scintillates", causing visible light proportional to radiation intensity. A photomultiplier then generates a current proportional to the light intensity, and inverse to plate thickness.

The photomultiplier current is subtracted from a constant current in a potentiometer to produce a voltage directly proportional to strip thickness. This signal is compared to a preset voltage representing desired strip thickness, and the difference goes to a highly-stable, low-gain dc feedback amplifier. The output of the amplifier is thus proportional to the deviation.

A discriminator receives the amplifier output and operates the screwdown motors through relays. It recognizes three zones of deviation and responds with either an intermittent or continuous correction action. In a dead zone accepting a thickness deviation of plus or minus 0.0003 in. it takes no action. When the deviation lies between plus or minus 0.0005 in., it sends 0.25-sec impulses at 2-sec intervals to the screwdown motors via the relays, and when the deviation is larger it operates the motors continuously. This control action is said to have better anti-hunting characteristics than systems in which correction is continuously proportional to deviation.

The system is self-monitoring against a standard. A microswitch on the in-going side of the mill is tripped when the tail of a strip passes. This causes the measuring hand to withdraw and the shutter to rotate, presenting a standard sample between the source and the detector. If the amplifier gets a deviation signal, its output is fed to a servomotor through another relay-discriminator circuit. This motor changes the setting of the potentiometer on the photomultiplier until a balance is reached and the amplifier output zeroes on the standard.

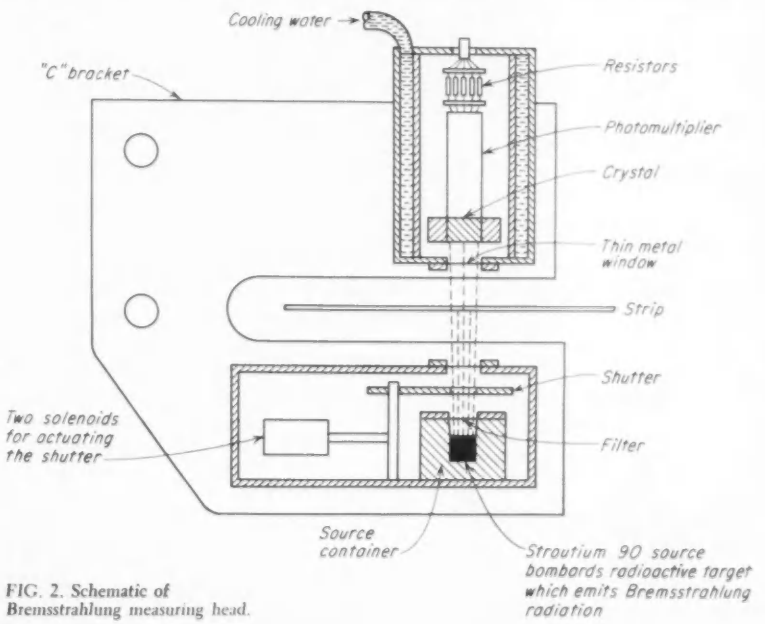


FIG. 2. Schematic of Bremsstrahlung measuring head.

An Airborne Correlator to Aid Data Reduction

H. B. MEYER, Convair (San Diego)

When flight-test data is partly telemetered and partly recorded locally, the parts must be correlated properly to get all the test results. A working correlator is described here in some detail.

During flight testing of experimental aircraft, the many temperature and pressure measurements telemetered to ground-based recorders often require the entire frequency modulation band of Research & Development Board (RDB) telemeter channels. However, it is also necessary to correlate these readings with other flight variables, such as air speed, altitude, electrical system load, and air temperature.

To save the telemeter channels for the pressure and temperature data, these other variables may be recorded by photographing a group of standard aircraft instruments arranged on a "photopanel". Then, by means of a common "key", the photopanel data can be correlated with the telemetered data at the time of data reduction. By dividing the telemetered data into specific groupings, each group can be coded (i.e., given an arbitrary name or number). The photographed data related to the telemetered data (i.e., taken at the same time) can be recognized by the same code. In this way, only one extra channel is needed—to transmit the code number. All other data can be correlated later.

An airborne system has been built that provides a correlation code to a special indicator on a photopanel, and to the data-correlation channel of the telemeter transmitter. This correlator also controls the grouping and multiplexing of temperature and pressure signals in two data channels, and the camera that records the photopanel.

The system is diagrammed in Figure 1. The master control unit is enclosed within the heavy box. It is designed around an electric-motor-driven commutator (sampling switch) that rotates at ½ rps and provides a master control pulse every revolution (2 sec).

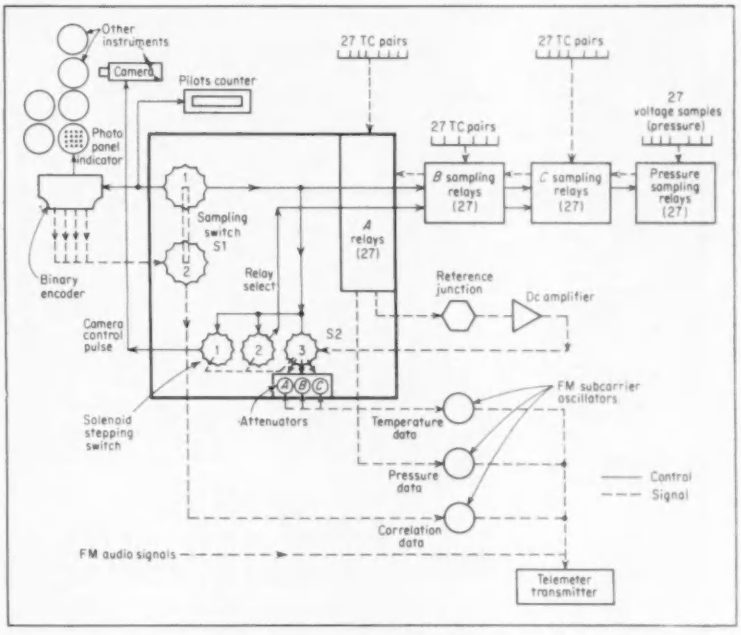


FIG. 1. Airborne data-correlation system.

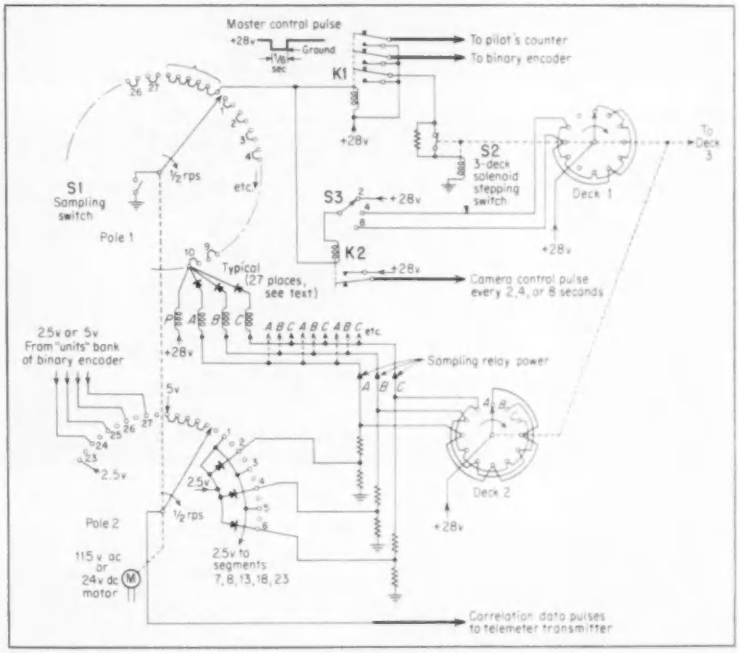
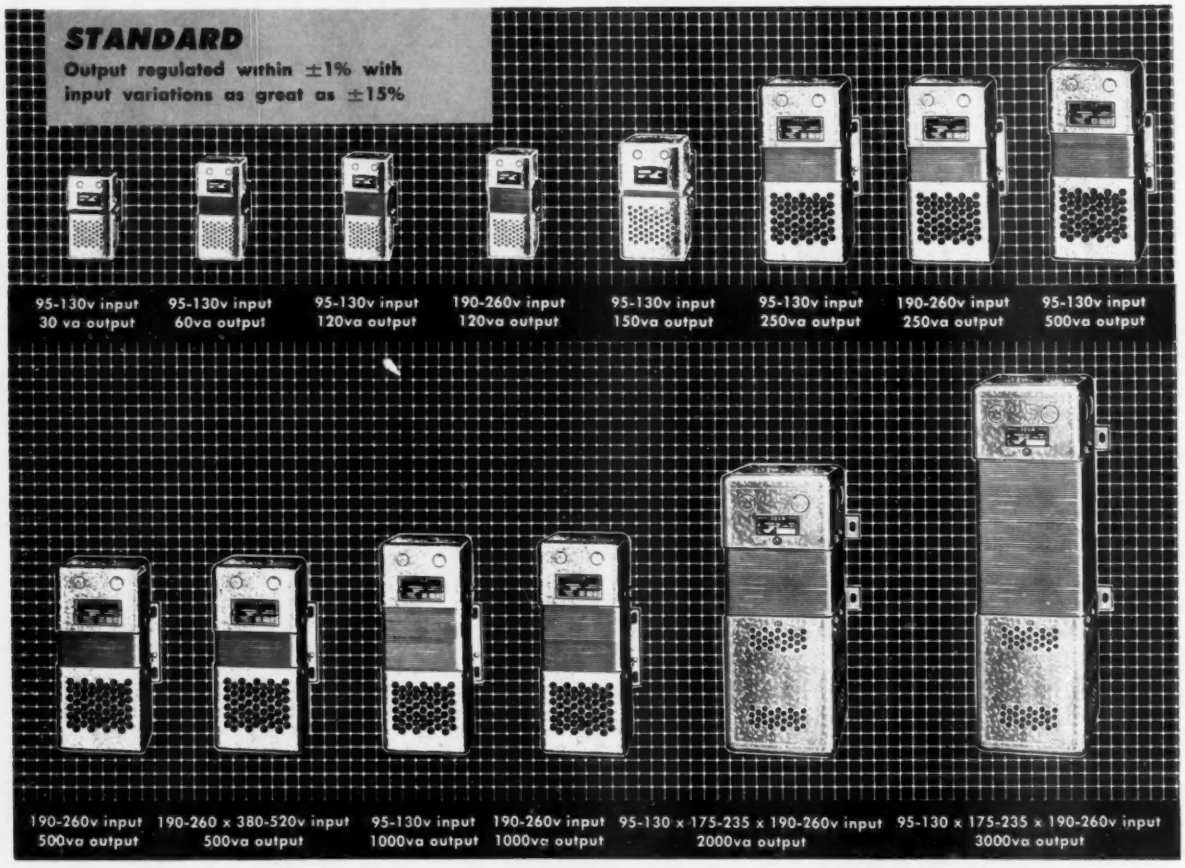
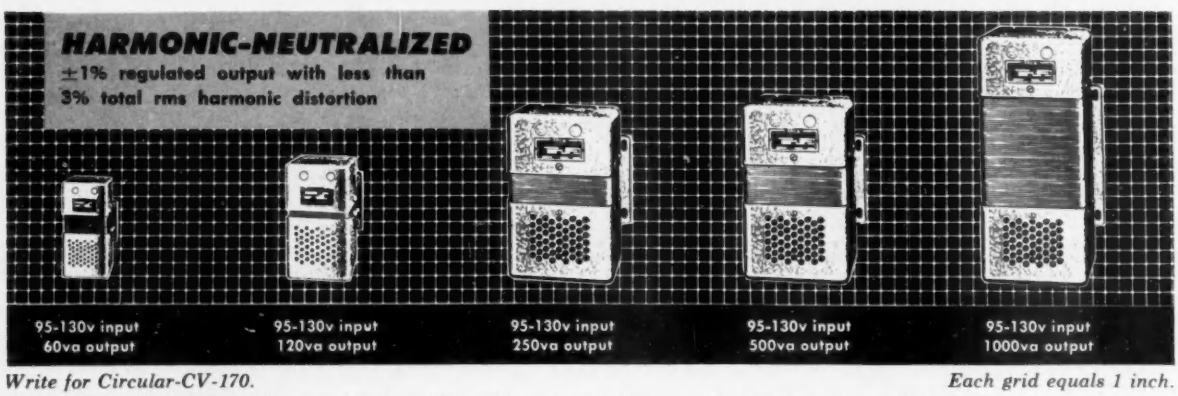


FIG. 2. Sampling-switch connections in data correlator.

New Sola Constant Voltage Transformers feature less size and weight; greater efficiency

Sola now has many improved designs in standard and harmonic-neutralized static-magnetic voltage regulators. These new designs — 19 in all — offer size reductions up to 60%, and weight reductions to 55%. Greater efficiency is achieved from improvements in core design. As with other Sola static-magnetic regulators, these new ratings provide output regulation of ±1%, with input voltage fluctuations up to ±15%. Response time is 1.5 cycles or less. There are no moving parts, no manual adjustments. These are but part of a full selection of 44 stock ratings from 15va to 10kva output capacity.





Write for Circular-CV-170. *Each grid equals 1 inch.*

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The sampling switch S1 (Figure 1) has two poles and 60 segments per pole. Pole 1 produces the master control pulse to actuate the camera and select the A, B, or C group of sampling relays. The first five segments of the switch are connected together to produce this pulse. The switch is the overlapping or make-before-break type, so the pulse is continuous for $\frac{1}{6}$ sec (5/60 rev divided by $\frac{1}{2}$ rps).

The master pulse closes relay K1 (Figure 2), producing three simultaneous pulses. One of these pulses advances an electromechanical counter which can be read by the pilot. The second pulse advances a special binary encoder which supplies the correlation code number to the indicator on the photopanel and to the correlation channel of the telemeter transmitter

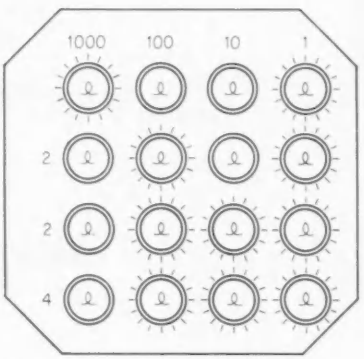


Fig. 4.
Photopanel indicator showing number 1,869.

via pole 2 of the sampling switch. More about this later. The third pulse from K1 advances the three-deck solenoid stepping switch S2 one position.

Switch S2 does three things. By means of a manual selector switch, S3, deck 1 permits camera-control relay K2 to be pulsed every 1, 2, or 4 revolutions of the sampling switch S1. Thus, a photograph of the photopanel can be made automatically every 2, 4, or 8 sec. Deck 2 of S2 distributes 28-volt dc power sequentially to each group (A, B, or C) of temperature-sampling relays on successive revolutions of the sampling switch S1.

Note that after producing the master control pulse on each revolution, pole 1 of S1 grounds 54 sampling relays per revolution, two at each double segment. The 27 pressure relays are permanently connected to 28 volts dc, and so are sampled at every revolution of S1. The A, B, and C groups of 27 temperature sampling relays are connected to 28 volts by way of deck 2 of S2, and so are sampled serially,

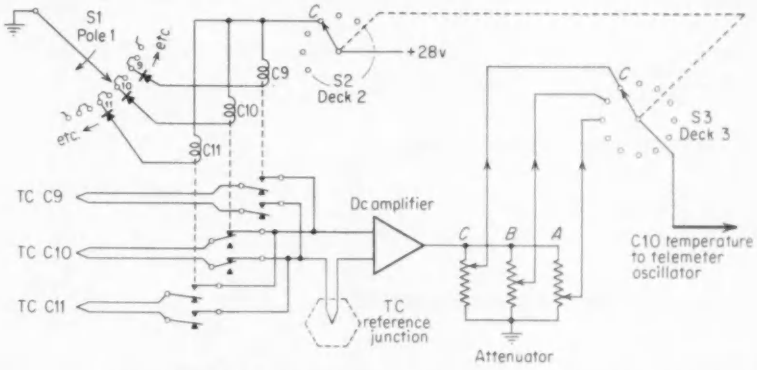


FIG. 3. How a specific temperature signal (C10) reaches the telemeter transmitter.

a group every third revolution of S1.

Figure 3 shows how a specific temperature reaches the telemeter transmitter. Three adjacent thermocouples in the C group appear here with their sampling relay connections to the dc amplifier. At the instant shown, pole 1 of the sampling switch is passing double segment 10 and relay C10 is being pulled in to connect thermocouple C10 to the dc amplifier. Other thermocouple leads, including groups A and B, are in parallel but open.

After the C10 signal is amplified, it is attenuated to the correct level to modulate the temperature-channel fm oscillator of the telemeter transmitter. Deck 3 of stepping switch S2 connects in the proper attenuator for the C relay group. The three attenuators permit the oscillator to handle three different temperature ranges, and retain comparatively high resolution on the lower ranges. In one application, the A thermocouples operated in the range from 400 to 600 deg F, the B thermocouples from 250 to 450 deg F, and the C thermocouples from minus 40 to plus 250 deg F.

Pole 2 of sampling switch S1 delivers a pulse-time code signal to the data correlation oscillator of the telemeter transmitter. The first five data segments are connected together to produce a 5-volt, $\frac{1}{6}$-sec pulse at the time of the master control pulse. This long pulse identifies the beginning of a new sampling period (revolution of S1) on the telemeter recording. The rest of the individual switch segments produce alternately zero output and either 2.5- or 5-volt pulses. Segments 1 through 6 (Figure 2) are connected to a resistance-diode network to produce a 2.5-volt pulse at each segment and, depending on which relay is being powered by S2, a 5-volt pulse at segment 2, 4, or 6.

The binary encoder is a relay counter that uses a 4-2-2-1 code to energize a photopanel indicator like that in Figure 4. It adds a count at each revolution of S1 as it receives a pulse from K1 (Figure 2), and in addition produces four groups of four signals (held for an entire revolution of S1) representing the thousands, hundreds, tens, and units decimal digits of its 9,999-digit capacity. A binary zero is represented by a 2.5-volt (steady) output and a one by a 5-volt output. These outputs of the encoder connect to the segments of pole 2, S1 as follows:

Thousands	— 9, 10, 11, 12
Hundreds	—14, 15, 16, 17
Tens	—19, 20, 21, 22
Units (shown)	—24, 25, 26, 27

A typical output of the data-correla-

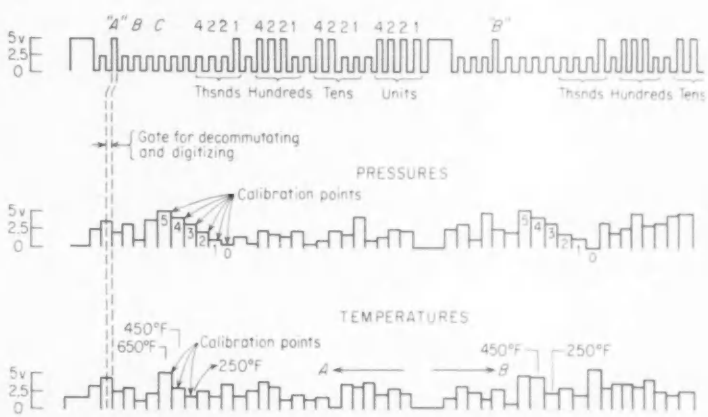
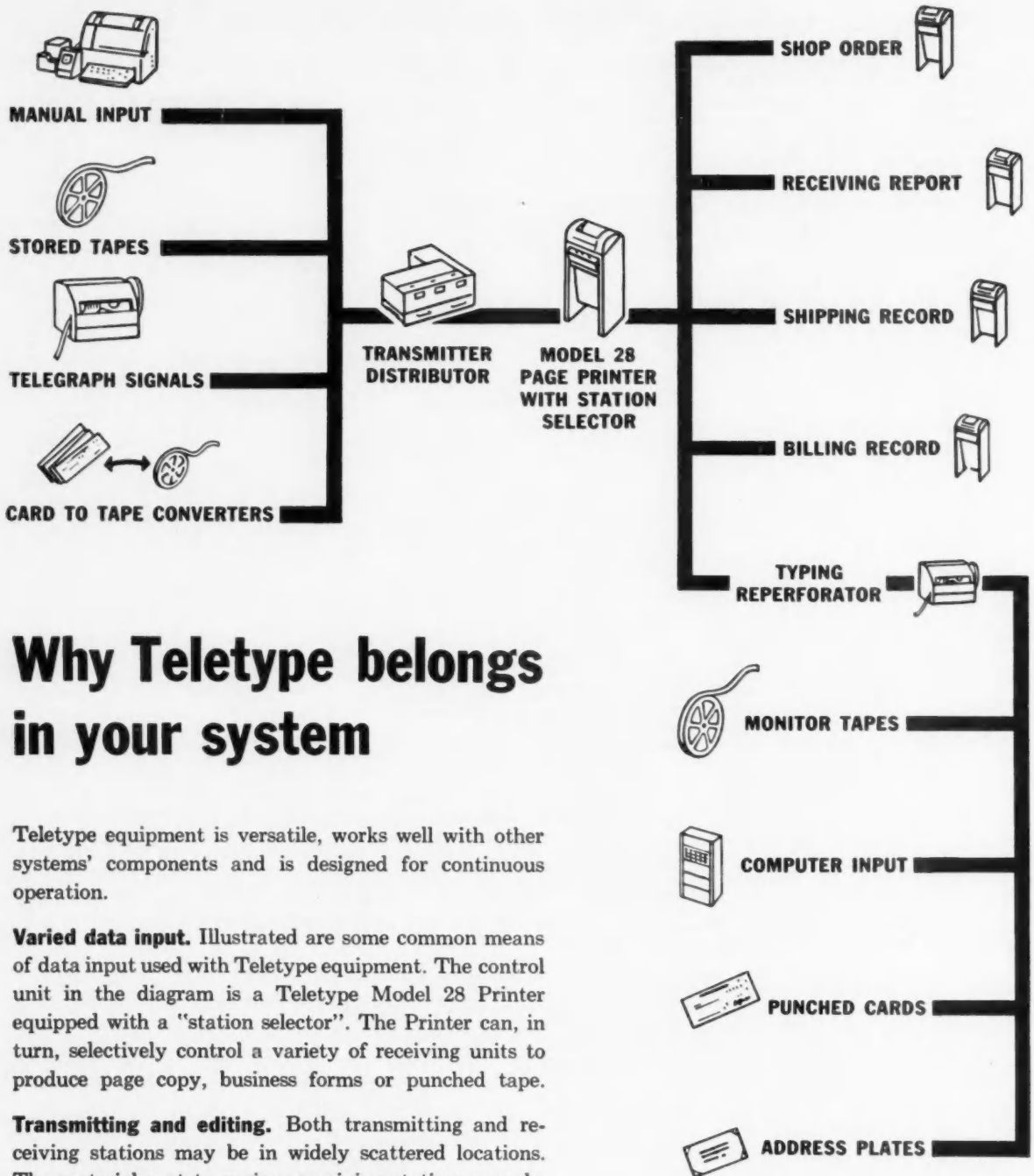


FIG. 5. Typical signals from data-correlation, pressure, and temperature channels of correlation system. Number coded in correlation channel is 1,869.



Why Teletype belongs in your system

Teletype equipment is versatile, works well with other systems' components and is designed for continuous operation.

Varied data input. Illustrated are some common means of data input used with Teletype equipment. The control unit in the diagram is a Teletype Model 28 Printer equipped with a "station selector". The Printer can, in turn, selectively control a variety of receiving units to produce page copy, business forms or punched tape.

Transmitting and editing. Both transmitting and receiving stations may be in widely scattered locations. The material sent to various receiving stations may be edited—some stations receiving all of the data, while others are blanked out during part of the transmission time. These latter stations thus receive only the portions of the data pertinent to their operations.

All locations receive their material without additional typing input.

For further information on why Teletype equipment belongs in your system, write to Teletype Corporation, Dept. 20 D, 4100 Fullerton Avenue, Chicago 39, Ill.

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tion channel is shown in Figure 5 with the temperature and pressure data sampled during two revolutions of S1. Note that calibrated voltages are sampled for both temperature and pressure channels on each revolution. The recordings shown were made after the attenuators, hence the difference between the *A* and *B* calibration signals.

Note that the correlation channel pulses are half as long as the pressure and temperature "pulses". The short pulses are used during ground-data reduction to gate the data samples, and thus reject any "rise time" due to the dc amplifier and any signal ambiguity due to the time overlapping of sampling relays. These gating pulses provide the means for ground-station conversion of the fm (analog) signals to digital.

The pilot can add his own data via the audio channel.

Change the Piping to Simplify Control

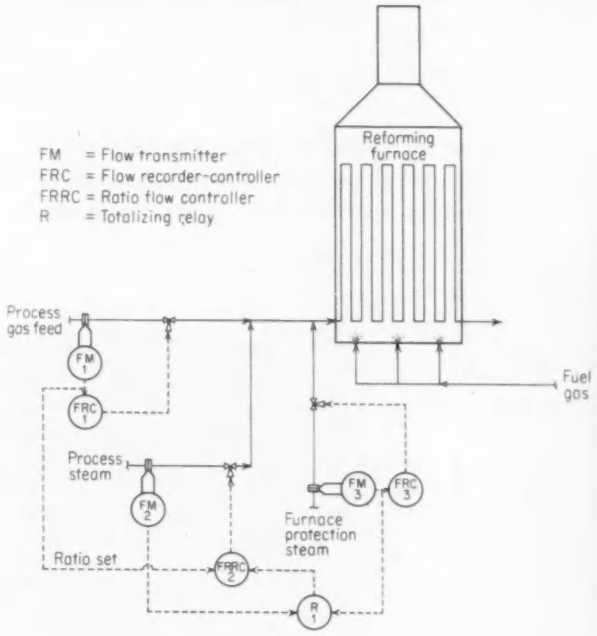
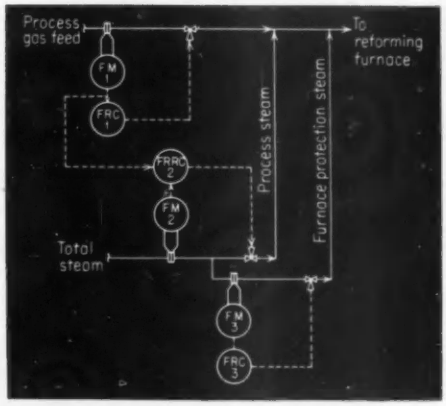


FIG. 1. Original piping arrangement required use of a hard-to-get totalizing relay R-1.

FIG. 2. Minor change in piping eliminated need for R-1, simplified control problem.



J. J. COMBES
Scientific Design Co.

Controlling the flow of process gas and steam to a reforming furnace looked like it would be very difficult until the possibility of making a minor piping change was considered. Then it became quite simple. The problem was stated thus by the process people:

"A process gas is fed to a reforming furnace at a constant controlled rate (as in Figure 1). Steam is fed into the process gas line at a rate controlled in a fixed ratio to the process gas stream. This ratio will be changed from time to time, depending on the source of the process gas. The steam is fed through two lines from the main steam header. In one line a small flow (about 20 percent of the total) is fed at a constant rate to protect the furnace tubes in the event the process gas and main steam flows are turned off. The other line provides the major flow of the process steam and is the one that is regulated to provide the correct total steam flow. The two steam flows must be totalized and the totalized signal sent to the ratio flow controller so that it can control total flow. The flow can probably be totalized with a totalizing relay."

The difficult part lies in obtaining a totalizing relay, *R*-1, that will send a signal to the ratio flow controller FRRC-2 that is truly representative of the total flow. That is, the signal must recognize that: a unit pressure change from differential pressure type flow transmitter FM-2 represents four times as much flow as the same unit pressure change from FM-3; and a unit pressure change from either transmitter at the lower end of its scale represents a greater flow change than a unit pressure change at the upper end of its scale, because flow is proportional to the square root of the measured differential.

The problem was simplified when the instrument-application engineer suggested that, instead of feeding steam from the main steam header in two separate lines, it be fed from one line only; i.e., that the furnace protection steam be taken off the main process steam line downstream of the process-steam orifice and upstream of the process-steam control valve. This arrangement is shown in Figure 2. It can be seen that the steam flows are totalized, since all the flow goes through the one orifice. The control requirements are met and the probably unobtainable totalizing relay *R*-1 is eliminated.

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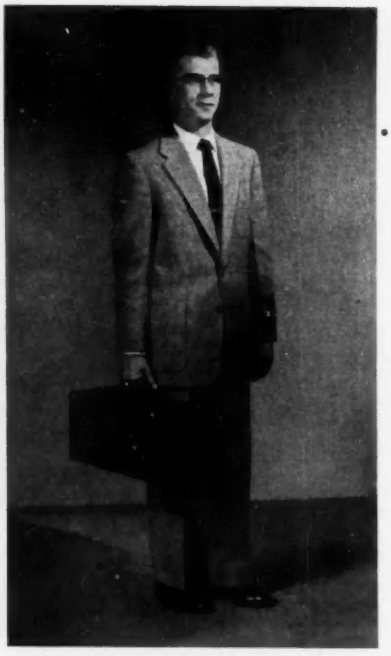

Bill Lewis, typical service engineer, proves how you can depend on Honeywell for fast, on-the-spot service even in emergencies.

3 It took Bill two hours to drive to the plant through the storm. He spotted the trouble immediately; a thermocouple and its protecting tube had burned out. It might have meant four to five thousand dollars' worth of damage.

Honeywell service begins when you first decide you need instruments, and continues long after they're installed. It includes:

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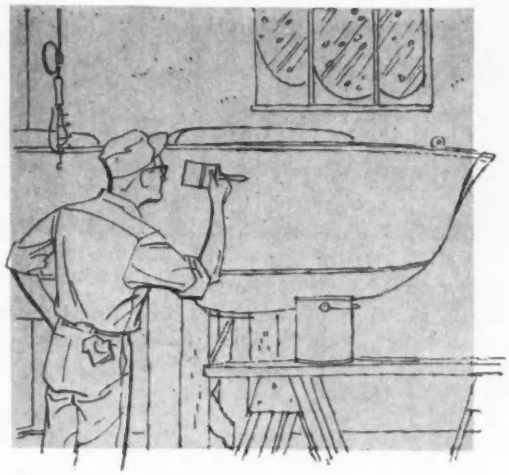
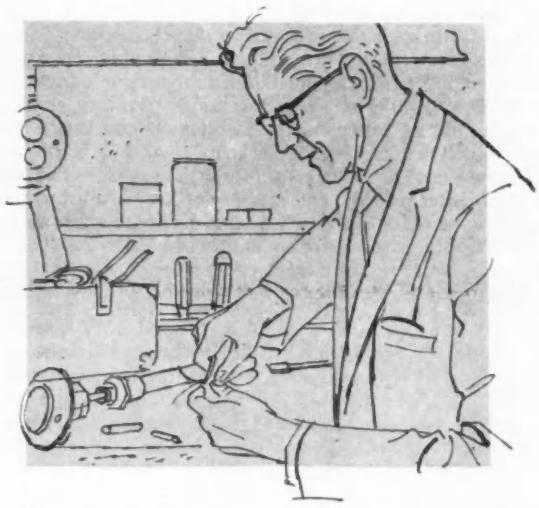
- Application engineering for installation and startup.
- Service engineering help from your nearby Honeywell branch.
- Periodic service and swift help in emergencies.
- Training of your operators at the Honeywell Instrumentation Education Center.



1 Bill Lewis, service engineer at Honeywell's Fort Wayne branch, was in his garage, touching up the paint on his 13-foot outboard. The bowling match had been called off that night because of the snowstorm, and Bill was glad to be home.

2 At 9:30 a call came from the Crosby Laughlin Division of American Hoist and Derrick Company in Fort Wayne. A controller on a galvanizing kettle wasn't working and unless it was fixed fast, the pot would either freeze or burn out. Bill said he would be out right away.



4 Bill didn't have a thermocouple with him that would fit, so he improvised a temporary couple and protecting tube and got the system going. Early the next morning he called the Honeywell branch in Indianapolis and had the correct thermocouple and tube shipped quickly to the plant. Next day, he carefully checked out the entire installation.

5 Now, Crosby Laughlin Division is signed up with the Honeywell Periodic Service Plan, and its complete instrumentation is checked and serviced every month. Any spare parts needed are now available at Honeywell's Fort Wayne branch. Bill hasn't had to make another emergency call to the plant since.

Around-the-clock help in emergencies is but one of many Honeywell services that give you extra value for your investment in instruments. Get the complete service story from your nearby Honeywell field engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Products Group* . . . Brown Instruments, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

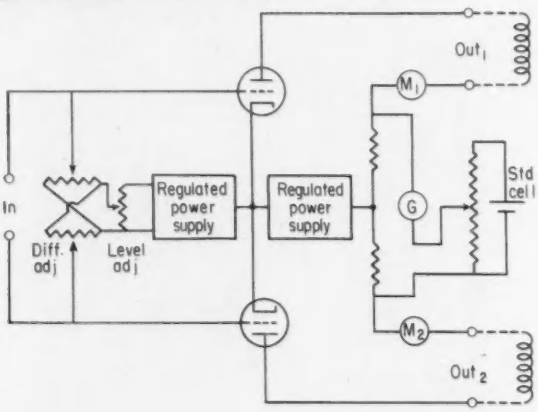
H HONEYWELL

First in Controls

NEW PRODUCTS

LISTING IN GROUPS

Designs of the Month
Data Handling & Display
Primary Elements & Transducers
Controllers, Switches & Relays
Power Supplies
Actuators & Final Control Elements
Research, Test & Development
Component Parts
Accessories & Materials



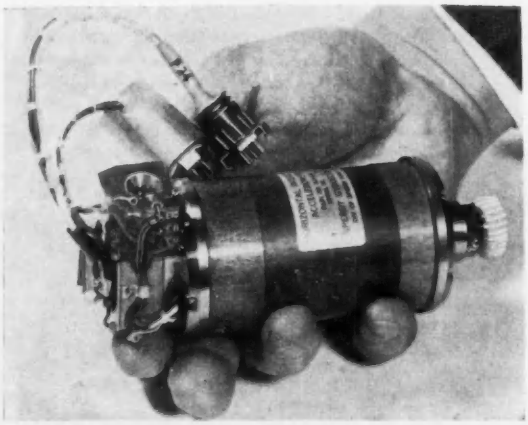
CURRENT BRIDGE calibrates transducers.

The photo and block diagram illustrate a new precision current bridge for testing or calibrating meter movements, relays, micropositioners, torque motors, and electrohydraulic servovalves, and for supplying precise dc currents to either single-ended or push-pull current-actuated devices.

Output current ranges from 0 to plus or minus 100 ma from either output, or when used as a differential current source, from both. A 0 to plus or minus 10 ma range may also be selected. Self-regulation holds error to within 1 percent for a line-voltage change between 105-125 volts, 60 cps. Three meters are provided; one in each output circuit, and a zero-center galvanometer that can do three things: check the standard cell voltage, indicate the differential output current, or serve as a null indicator when the bridge circuit is used for precise current measurements. The bridge circuit uses a mercury cell as a standard voltage source.

There are control switches for power, standard cell calibration, null meter polarity, and range selection. Multiturn pots accommodate level, differential, and bridge circuit adjustments. Its design also provides a pair of auxiliary input terminals and two pairs of output current terminals, separately fused.—American Measurement & Control, Inc., Waltham, Mass.

Circle No. 1 on reply card



SPACE SPEEDOMETER yields top results.

Actually an integrating accelerometer, this compact instrument boasts a threshold sensitivity of better than 10^{-6} g's. Teamed with gyros on mutually perpendicular axes, several instruments of this kind can microscopically measure velocity in any direction of spherical space. Proposed applications include the guidance systems of winged missiles and aircraft through the high supersonic or low hypersonic range.

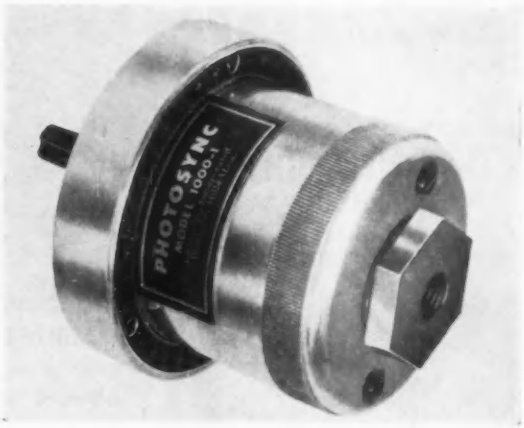
The device consists of three small metal cylinders. The smallest (internal) cylinder floats in a silicone fluid inside the middle cylinder. Hydrostatic forces, caused by rotating the middle cylinder at 1,000 rpm, center the inner cylinder and make it very sensitive to acceleration along its longitudinal axis.—Sperry Gyroscope Co., Great Neck, N. Y.

Circle No. 2 on reply card

ROTARY SWITCH uses optical techniques.

Called the Photosync, this rotary cam-type switch uses electro-optical techniques to eliminate such problems as low resolution, cam wear, contact bounce, and slow response. A direct-coupled voltage change results whenever the input shaft angle crosses one or more sets of predetermined angular settings. An optical shutter, mounted on the shaft, gates the light path between a 10,000-hour incandescent lamp and a variable-resistance-type phototransistor. After installation, the dust-tight cover assembly may be rotated to correct mechanical phase alignment. Shutters can be cut for any angular limits between 0.1 and 358 deg. For shaft speeds under 5,000 rpm, electrical response time is essentially independent of speed. —Automation, Inc., Wellesley Hills, Mass.

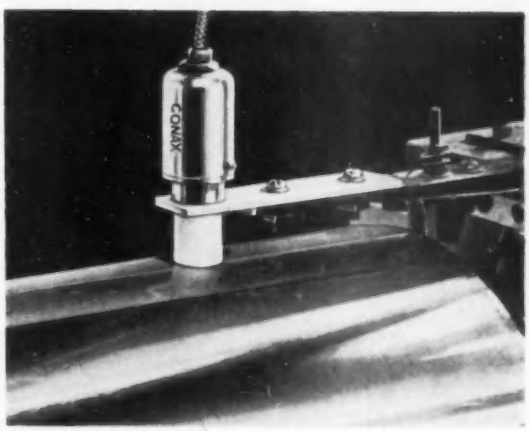
Circle No. 3 on reply card



NEW T'COUPLE checks roll temperature.

Designed for accurate measurement of surface temperature on rotating rolls, shafts, and bearings, this new thermocouple assembly features fast response, compact design, and long life. Its sensing element is a brass plug, flush mounted in a spring-loaded Teflon plunger. The plunger bears against the roller or shaft, shielding the junction from the surrounding air. In this way the temperature reading remains unaffected by changes in surface speed. The internal spring assures a constant bearing pressure, while the natural lubricity of the Teflon prevents any build-up of friction heat. Copper-constantan, iron-constantan, or chrome-alumel calibrations are available.—Conax Corp., Buffalo, N. Y.

Circle No. 4 on reply card



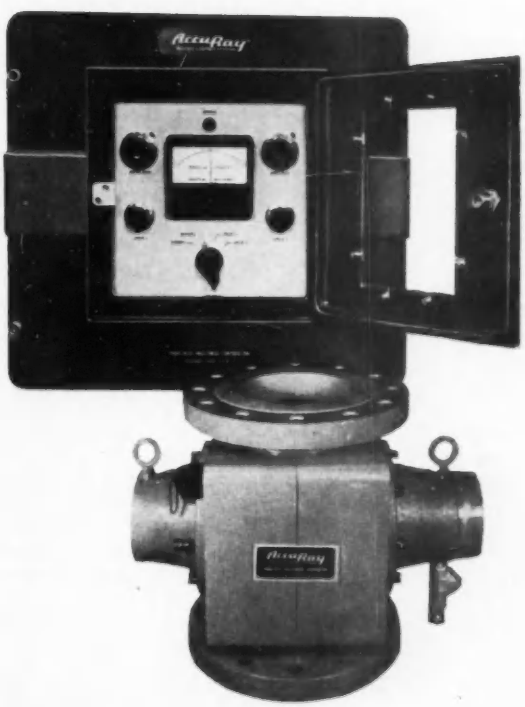
DENSITY SYSTEM features rugged construction.

Properties such as fluid density, specific gravity, and percent solids are readily measured and/or controlled by the new AccuRay Density System shown here. Applicable to liquids, slurries, and divided solids, the system operates on the principle of gamma-ray transmission from a radioistotope. There is no physical contact with the flowing material and measurement is independent of flow rate and pressure.

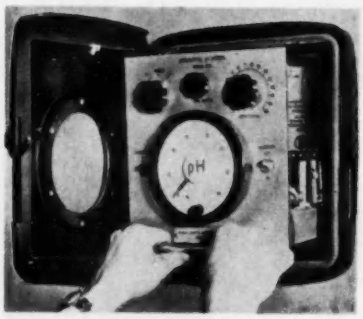
The system's built-in standardizing circuits maintain accuracy and calibration; any component except the radiation source and detector may be replaced without affecting this calibration. Automatic, built-in temperature compensation is also available. Long-term accuracies to within plus or minus 0.001 to 0.003 on specific gravity readings can be obtained.

In the measuring head, standard pipe sizes range from 3 in. to 8 in. The head itself consists of heavy, corrosion-resistant meehanite castings welded to the pipe section. Its rugged construction provides maximum stability under the most adverse industrial conditions. The power supply and amplifier are housed in the enclosure shown, which may be remotely located. Its features include a locking access door, slide-out electronic unit, and a modular chassis arrangement. A recorder may be mounted separately.—Industrial Nucleonics Corp., Columbus, O.

Circle No. 5 on reply card



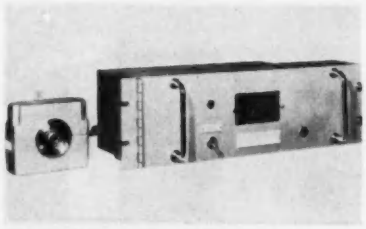
DATA HANDLING & DISPLAY



FOR INDUSTRIAL pH

The Model 28A pH Meter, shown above, automatically compensates for zero shift and slope change of the pH-mv curve due to temperature changes. A carefully designed circuit and feedback system provides a stability of plus or minus 0.02 pH per 24-hour period. The instrument provides a built-in stability check control, and features a completely sealed air purge case. A wide range of electrode systems is available.–EIL Instruments, Philadelphia, Pa.

Circle No. 6 on reply card



POSITION INDICATION

A new series of digital position indicating devices provides a continuous indication of a shaft position on a digital display, as shown above, or on some recording medium. Models are available to indicate feet and inches to one millionth of an inch; angles to hundredths of a minute; and time to hundredths of a second. These systems use standard Datex encoders (left of display in photo), designed to read out continuously at shaft speeds up to 120 rpm.–G. M. Giannini & Co., Inc., Monrovia, Calif.

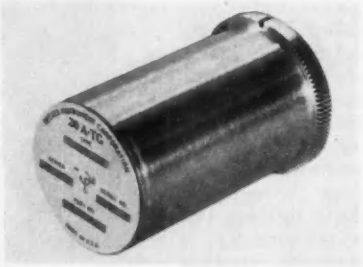
Circle No. 7 on reply card

COMPACT COMPUTER

This new desk-type, completely transistorized computer, called the Electronic Computation System (ECS), is designed to fill the computing needs of small and medium-sized firms. Figures are entered into the system on the keyboard and results printed out automatically on a print unit mounted flush with the desk top. The programming unit, also located on the desk top, provides extreme flexibility. When certain programs are used often enough, they can be preset on a program cartridge and plugged into the panel in a matter of seconds. Current price of the unit is $15,000.–Clary Corp., San Gabriel, Calif.

Circle No. 8 on reply card

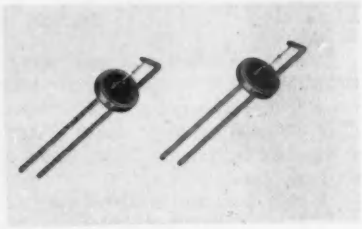
PRIMARY ELEMENTS & TRANSDUCERS



LINEAR G-METER

These new linear accelerometers use torque generator restraint instead of a torsion bar, and offer high precision in closed-loop servo systems. Flotation of the unbalance weight not only removes load from the jewelled bearings, but provides viscous damping and shock absorption. Models for detecting angular acceleration are also available. Torque generators can be supplied for either ac or dc operation.–Reeves Instrument Corp., New York, N. Y.

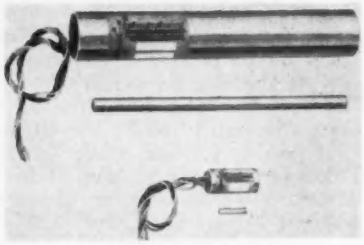
Circle No. 9 on reply card



FOR GAS ANALYSIS

Matched thermistor assemblies are now available for use in gas chromatography and other analytical techniques. With the assembly suspended in helium at a controlled 25 deg C, voltages are matched to within 0.030 volt. Bead resistances are also matched, to within 5 percent.–Fenwal Electronics, Inc., Framingham, Mass.

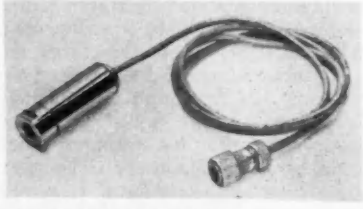
Circle No. 10 on reply card



IMPROVED LINEARITY

Available in many sizes, this new displacement transducer features a longer linear range and higher output than earlier models. Nonlinearity ranges from 0.1 to 0.5 percent. Larger units, with linear ranges up to 1 in., are well suited for industrial applications, while miniature models should find use in missile designs. Stainless steel or magnetic shielding is available.–International Resistance Co., Philadelphia, Pa.

Circle No. 11 on reply card



VERSATILE GAGES

Using unbonded strain wire, a new line of pressure transducers offers accurate and reliable measurements under extreme environmental conditions, such as are found in hydraulic and pneumatic lines in aircraft and missiles, the bottom of oil wells, gas and

. . . Fluid Power news

REPORT No. 11,702

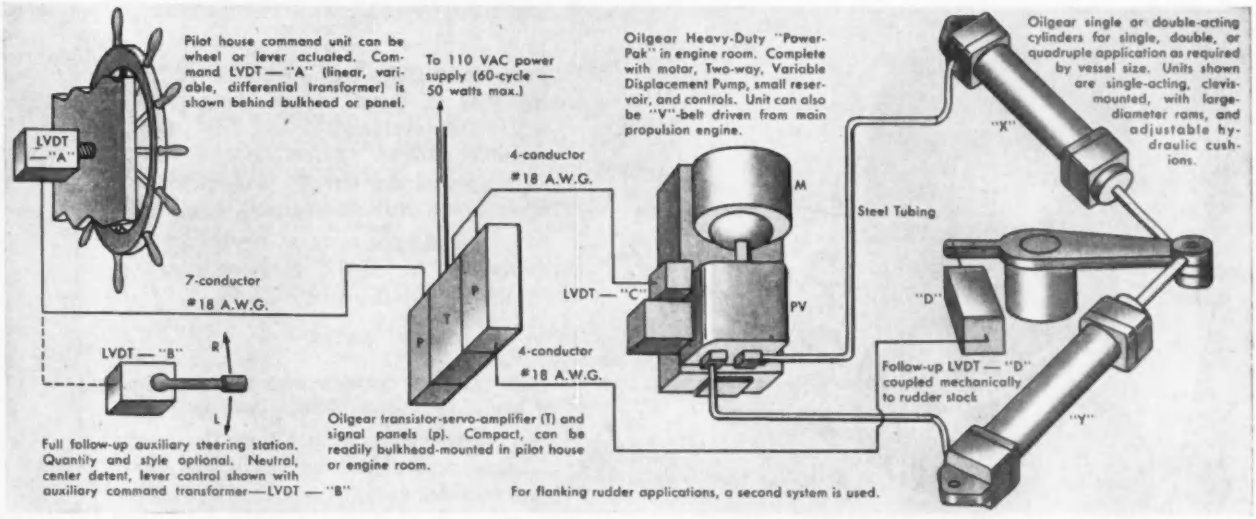
NEW MARINE STEERING CONCEPT

From Oilgear Application-Engineering Files

HOW OILGEAR APPLICATION-ENGINEERING AIDED CREATION OF MODERN MARINE STEERING GEAR

CUSTOMER: *A long-established Marine Engineering Company (name on request)*

DATA: This company's technical staff concluded that marine steering gear could be modernized instead of merely being made larger and heavier. A design program to incorporate new electric and hydraulic developments had the following basic objectives. 1: Extreme flexibility for normal application on all vessels requiring power steering. 2: New economy in system weight, size, and installed cost. 3: Simplicity, accuracy, reliability. 4: Full follow-up pilot house and auxiliary station control of rudder movement, speed, position. 5: Eliminate make-and-break, or sliding electrical contacts, relays, vacuum tubes, solenoid valves, heavy shafting, gears, racks, and linkage in the control system. Smooth, positively indexed, rate responsive, stepless rudder movement control that is noise, shock, vibration, and pulsation-free. 7: Compatible with gyro-compass, automatic steering.



SOLUTION: Above schematic symbolizes an Oilgear Fluid Powered, electrically controlled, marine steering system utilizing the newest electric-hydraulic developments. *Actual installations using this new Oilgear "electro-feedback-hydraulic-servo-control system" have exceeded ALL of the customer's original engineering objectives* . . . proof of Oilgear's cooperation and teamwork to help solve design engineer's problems. Oilgear Heavy-Duty "Power-Paks" are complete, ready-to-install power units in sizes and types to meet every marine need. No auxiliary valves, pumps, controls, reservoirs, or "plumbing" are required. Oilgear "Custom-Quality" single and double-acting cylinders can furnish the "muscle" to control any type vessel. Oilgear ServoControl Division's rugged, compact transistor-servo-amplifier and control system is further proof of Oilgear progressive, pioneering, engineering service. Connections between the amplifier and signal generators can be made by any competent electrician.

In every industry, manufacturers and users recognize and trust the name "Oilgear" for dependable, lowest-cost-per-year operation.

For similar practical solutions to YOUR linear or rotary Controlled-Motion problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

THE OILGEAR COMPANY

Application-Engineered Controlled Motion Systems

1587 WEST PIERCE STREET • MILWAUKEE 4, WISCONSIN

OPERATION: LVDT units (A, B, C, D) are actually coils with a core or slug moved axially in the coil airgap. When core is at central position there is a "null" signal. Maximum signal is emitted at maximum limits of travel — either "in" or "out." Movement of wheel or steering lever displaces core of command LVDT (A or B), producing a signal that is compared in transistor amplifier (T) with the signal from rudder stock coupled LVDT (D). Resulting difference between these two signals is called the "error" signal — built up to usable current strength by amplifier (T). Amplified signal is applied to an AC torque motor on Oilgear Two-way, Variable Displacement Pump (PV), imparting movement in amount and direction as ordered to a hydraulic servo valve — stroking pump (PV) to supply ordered direction and volume to rudder actuating cylinders (X, Y). As rudder moves, coupled LVDT (D) is displaced to reduce error signal to zero — at which point the cycle is complete. During this cycle, pump LVDT (C) has also been sending its signal to the amplifier for comparison, insuring that pump output is always under error signal control. Rapid motion of the command wheel or lever generates a large error signal, resulting in full rudder speed. Similarly, a slow command movement results in a slow rudder speed.

RIGHT: Oilgear Size 3, Heavy-Duty "Power-Pak" with Two-way, Variable Displacement Pump, motor, reservoir and controls . . . "as shipped," ready for installation with an "electro-feedback" system described above. This unit is now in use on a new 144' x 55' x 5' draft ferry boat of 483-ton displacement.

Similar Oilgear Systems are being used to control motion in all industry.

POSITIVE CONTROL OF MATERIALS IN MOTION B·I·F

LOW COST STEAM AIR, GAS METER

Self-Operated! Self-Contained!

FOR ACCURATE ACCOUNTING of steam, air or gas usage by process, department or building. Meters are available *in 1" to 24" line sizes,* are as *easily installed* as a valve or fitting, require *minimum space,* and provide *extra safety* through magnetic drive coupling. Shuntflo makes cost distribution and billing more accurate.

FOR AUTOMATIC PROPORTIONAL PACING of liquid proportioning pumps and/or dry chemical feeders. For pacing, Shuntflo utilizes electric impulse meter signals which are directly proportional to flow. Signals can be used directly or through timers when time duration signals are required . . . for digital read-out systems, remote counters, recorders or demand meters.

FOR BUYING OR SELLING STEAM, *continuous and automatic pressure compensation* prevents unintentional steam give-away . . . even in installations subject to wide pressure fluctuations. Shuntflo offers *high accuracy* . . . to within ±2% of actual rate of flow over specified range. *Open upper limit* allows temporary overloads up to 150% without affecting accuracy.

FREE LITERATURE

Please send me the POSITIVE FLOW CONTROL bulletins checked below:

- ☐ Shuntflo Bulletin (400-J10A) . . . for metering air, gas, steam
- ☐ Propeloflo Bulletin (380-K4B) . . . for metering water
- ☐ Conveyoflo Bulletin (550-P5) . . . for weighing belt-conveyed materials
- ☐ Chronoflo Bulletin (230-H4B) . . . for telemetering and control
- ☐ Hi-P, Hi-T Flow Nozzle Bulletin (115-P4) . . . for high pressure, high temperature metering
- ☐ Dall Flow Tube (DFT-PI) Bulletin (125-P3) . . . for low cost, specialized metering

Save air, gas, steam! Save $ $! ! Write for new 16-page Shuntflo Bulletin . . . to **Builders-Providence, Inc. 528 Harris Ave., Providence 1, R. I.,** manufacturers of precision instruments and equipment for the *positive control of materials in motion.*

Name.....

Company.....

Address.....

City.....*State*.....

BUILDERS-PROVIDENCE
DIVISION OF
B-I-F INDUSTRIES B·I·F METERS FEEDERS CONTROLS

NEW PRODUCTS

oil pipelines, and chemical processing vessels. The instruments are insensitive to vibration and acceleration, and operate in temperatures of from minus 100 to plus 300 deg F with very little thermal shift. Pressure ranges of 25 to 300 psi are standard.–Gulton Industries, Inc., Metuchen, N. J.

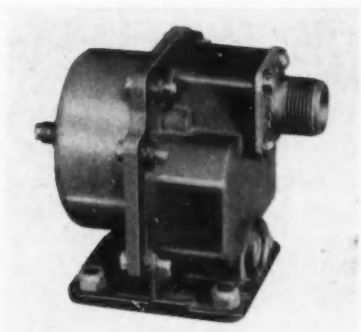
Circle No. **12** on reply card

CONTROLLERS, SWITCHES & RELAYS

SHOCK RESISTANT

Design changes in the new Series PW miniature-tube relay have effected a 30 percent increase in shock and vibration resistance, and a 50 percent drop in power consumption. The unit operates on 40 milliwatts under shocks of 30 g's and vibrations of 10 g's to 500 cps. It will handle currents to 6 amps and voltages to 115 vdc.–Potter & Brumfield, Inc., Princeton, Ind.

Circle No. **13** on reply card



NEW PRESSURE SWITCH

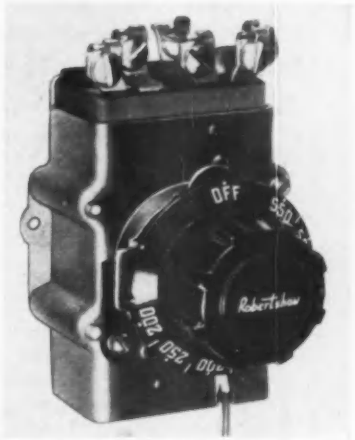
Primarily intended for direct control of pressure in an air pump motor circuit, this new switch can also operate low-pressure warning lights, interlock controls, etc. Actually a spdt switch, it controls under increasing or decreasing pressures and will operate in either dc or single-phase ac circuits with a current load of 10 amps resistive. The unit will perform without chatter over the full operating pressure range, at any applied vibration from 10 to 500 cps and 10-g acceleration.–Lear, Inc., Elyria, O.

Circle No. **14** on reply card

PRESSURE CONTROL

Shown is one model of the Type H95 explosion-proof pressure controller designed for operation in hazardous locations. An external adjustment knob and calibrated dial permit rapid changes in pressure settings. Models are available with adjustable ranges between the overall limits of 0 and 500 psi. Maximum design pressure is 600 psi. Switch differentials range from 1.5 in. Hg to 7 psi; units can be supplied with any one of three standard types of snap action switches.–United Electric Controls Co., Watertown, Mass.

Circle No. **15** on reply card



CONTROLS THREE PHASES

The Model D33 three-phase electric thermostat is available in nine temper-

NEW PRODUCTS

ature ranges and has an electrical rating of 20 amp at 250 vac. The unit is designed to control three heating phases, one of which is on continuously when the dial is moved from the "off" position. The other phases are controlled thermostatically, and cycle automatically with changes in temperature. Features include silver contacts and bridges, and hardened steel levers and supports.—Thermostat Div. of Robertshaw-Fulton Controls Co., Youngwood, Pa.

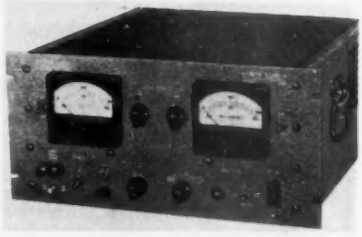
Circle No. 16 on reply card

TWIN-CONTACTS

A new line of ac-dc choppers featuring a novel twin-contact arrangement were exhibited last month at the IRE show. Two independently adjustable, parallel-connected contacts are used for a total of four spdt and eight dpdt arrangements. Use of a Mu-metal case virtually eliminates electrical noise and thermal emf's. Case measures 1¼ in. by 1 in. by 2⅛ in. Eleven different models, spdt or dpdt, are available for operation on 50, 60, 94, or 120 cycles.—Stevens-Arnold, Inc., South Boston, Mass.

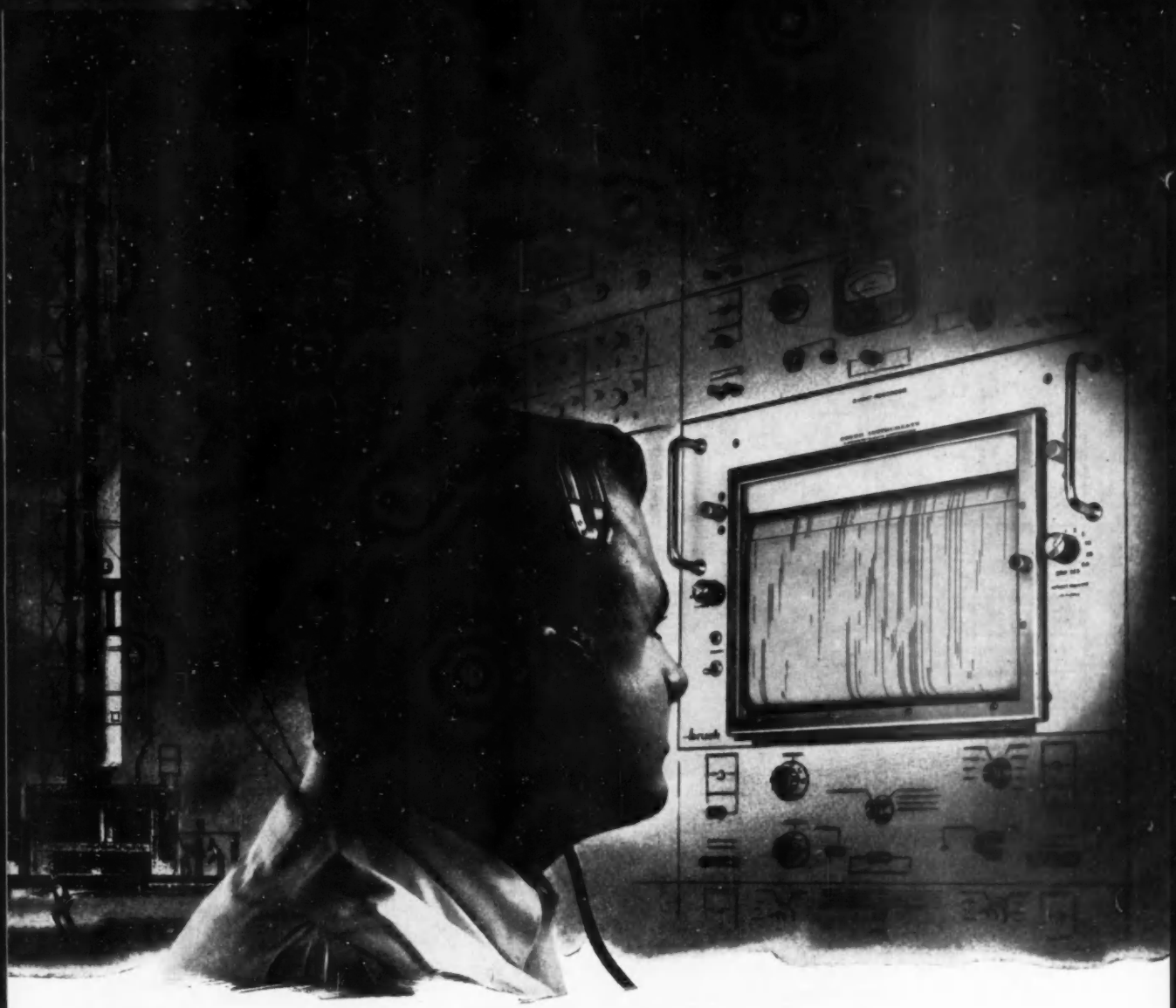
Circle No. 17 on reply card

POWER SUPPLIES



ELECTRONIC LOAD

The Model 910B Power Supply Variable Load is a vacuum tube load that operates in the range of 0 to 600 volts and 0 to 600 ma. Load is varied by varying the grid bias in the tubes. For any particular setting of load current, the grids of the tube load are con-



Simplify complex checkouts . . .

MONITOR 100 CHANNELS OF INFORMATION—*SIMULTANEOUSLY*

Unique and compact, the new Brush Event Recorder greatly minimizes the amount of time, space and equipment needed to perform complex checkouts on critical systems and processes.

On a moving chart only 12″ wide with a length of 500 feet, as many as 100 channels of sequential or operational information may be recorded simultaneously—indicating any number of events pertaining to electrical or physical phenomena.

The make-break of a relay, for example, can show as a break in a continuous trace or as a new trace; and the event itself is shown in a time relationship to all other events. Thus, you have an immediate picture of an entire situation at any time. Electric writing styli record in less than one millisecond after receiving a signal . . . handle up to 500 signal changes per second! Sixteen electrically controlled chart speeds may be selected from remote or on-the-spot locations.

Purposely designed to easily adapt to military specs, the new Brush Event Recorder is an ideal checkout instrument for use with industrial as well as defense equipment. Send for detailed literature, or ask for application assistance from your Brush factory branch or representative.

brush INSTRUMENTS

DIVISION OF

3405 PERKINS AVENUE CLEVITE CORPORATION CLEVELAND 14, OHIO

NEW PRODUCTS

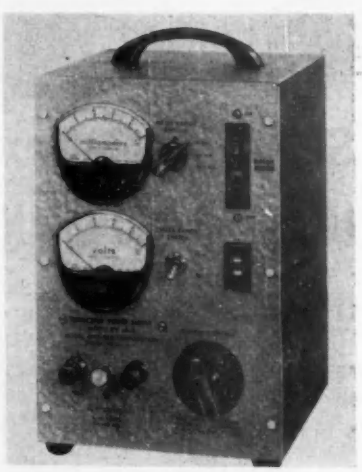
trolled by an amplifier that maintains a constant current from the power supply over the entire voltage range.—Kepco Laboratories, Inc., Flushing, N.Y.

Circle No. 18 on reply card

PORTABLE POWER

Designed for lab work or as a quick source of dc power, this portable unit maintains precise voltage control during large transient or steady state variations in load current or line voltage. It supplies up to 4 amp at 28 vdc and operates from a 105-to-125-volt, 400-cycle source.—Magnetic Controls Co., Minneapolis, Minn.

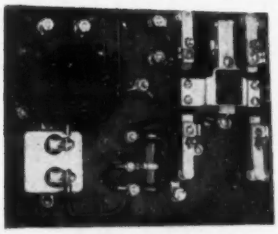
Circle No. 19 on reply card



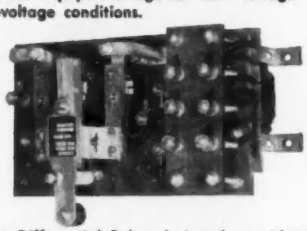
POWERS TRANSISTORS

The DV60-2 Transistor Power Supply shown above features ripple attenuation down to a maximum of 0.05 percent at full rated output. This compact, precision-made unit, designed for developmental and experimental transistor work, delivers 0 to 60 vdc at currents up to 1,000 ma, and,

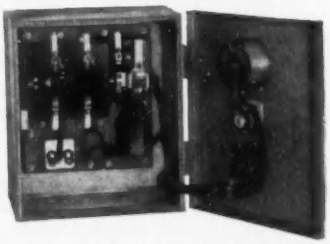
ASCO close differential relays respond crisply to 2% voltage or current variations... with no chattering on pickup or dropout.



Voltage Type Close Differential Relay protects electrical equipment against low voltage or over-voltage conditions.



Close Differential Relay designed to withstand NAVY Hi-shock requirements. Has tapped transformer making the relay suitable for a series of different pickup and dropout voltages.



Current type Close Differential Relay Panel for process control. (Relay operates as a function of motor load current.) Has adjustable pickup and dropout control. Panel has been used successfully for controlling cotton baling equipment.

ASCO Close Differential Relays (available either A-C or D-C) have been developed to meet the demand for a unit having the ruggedness of a power relay yet retaining the sensitivity of a primary control relay.

FEATURES

• Positive action on make or break, with no tendency to creep on opening or closing • 2% Sensitivity • Wide Variety of Applications • Available in Various Pole Combinations Up To 2 Normally Open and 2 Normally Closed Poles • Continuously Adjustable Pickup, or Variable Pickup By Tap Changing is Available • Continuous Dropout Adjustment is Standard.

MODIFIED ARRANGEMENTS

• High Shock Design • Variable Pickup • Frequency Response • Delayed Action • D-C Relays Also Available.

APPLICATIONS

As Voltage Relays they are extensively used in power and lighting systems to protect electrical equipment against low voltage or over-voltage conditions. For example... they permit detection where motor feedback conditions would not permit detection by ordinary potential relays. These relays are regularly furnished with ASCO Transfer Switches to provide voltage supervision of single phase and polyphase systems.

As Current Relays they have found extensive application as off-peak load relays to automatically disconnect selected loads, preventing system loading beyond set values. Close differential detection makes ASCO Close Differential Relays ideal for process control by motor current measurements.

Close Differential Relays are only part of the complete line of Relays offered by ASCO. ASCO Catalog 57-S4 lists:

• MAGNETICALLY HELD RELAYS
AC or DC . . . Normally Open . . . Normally Closed . . . Double Throw
• MECHANICALLY HELD RELAYS
AC or DC . . . All pole combinations

• SPECIALIZED RELAYS, INCLUDING:
. . . Reverse Current
. . . Time Delay
. . . Brake Winding Time Delay
. . . Close Differential
. . . Current Type, Welding
. . . Electronic
. . . Modified Arrangements

VISIT US AT THE DESIGN ENGINEERING SHOW BOOTHS 481, 483 AND 485

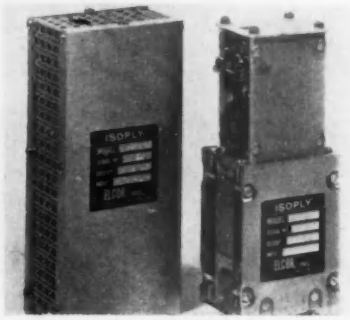
Write for your copy of "Relays by ASCO"— Catalog 57-S4.

Automatic Switch Co.
50-G Hanover Road, Florham Park, New Jersey
FRontier 7-4600

ASCO®

according to the manufacturer, eliminates the erratic operation usually associated with conventional high-voltage vacuum-tube types. Conservatively rated and ac-line operated, the DV60-2 has no moving parts. Its circuitry includes a continuously variable autotransformer, a full-wave selinium bridge rectifier, and a two-section choke input filter.–Model Rectifier Corp., Brooklyn, N. Y.

Circle No. **20** on reply card



LOW-NOISE SUPPLIES

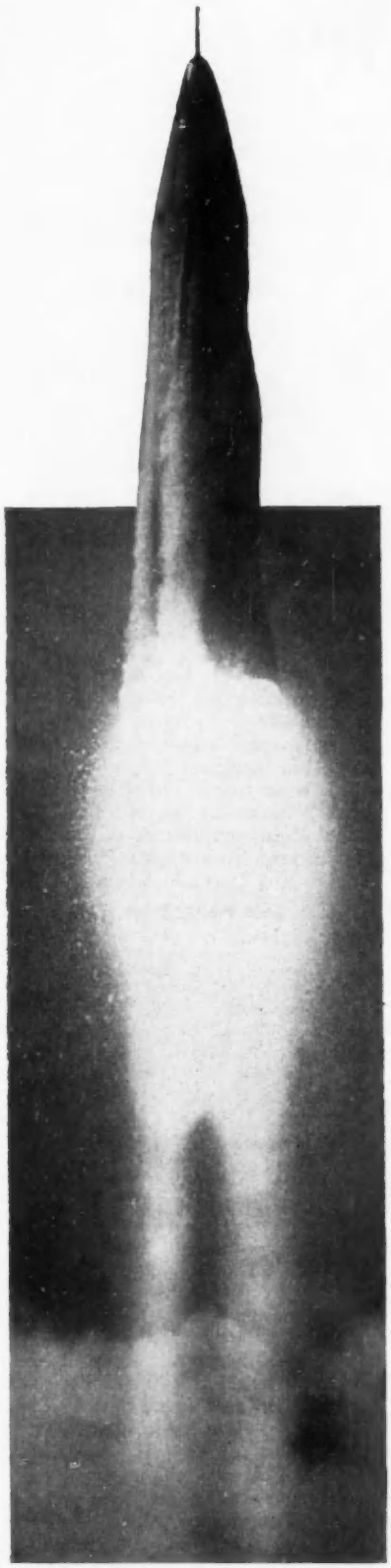
All nine models of these units are suitable for strain gage bridges and other applications requiring a low-noise ungrounded power supply. They operate on a 117-volt, 60-cycle input with output voltages ranging from 10 to 50 volts in 5-volt steps. Output current ratings range from 150 ma dc at 10 volts to 40 ma dc at 50 volts. Dimensions are 1 1/8 by 2 1/8 by 5 1/8 in. and weight is approximately 1 lb. Output ripple is 0.01 percent; hum and noise are less than 15 microvolts per 1,000 ohms impedance to ground.–Elcor, Inc., McLean, Va.

Circle No. **21** on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

FEATURES NEW SEAL

The new SV-4900 multipurpose solenoid valves, two-way, normally-closed units, feature a unique plunger seal design that assures bubble-tight sealing. They have a stainless-steel internal construction and a brass body, will operate in any position, and are easy to disassemble and clean. A 7/64-in. orifice is rated for 130 psi; a 1/8-in.



First test firing of the ATLAS ICBM at Cape Canaveral, Florida, June 11, 1957.

Honeywell Rate Gyro
Type JRT
Shown ½ size

Flight Control for the ultimate weapon

Three Honeywell Rate Gyros, Type JRT, provide missiles with precise three-axis directional stability and are currently being supplied to the ATLAS missile program.

The Type JRT is a highly accurate precision instrument for measurement of absolute rates of rotation in inertial space. Viscous damping is electro-mechanically controlled to maintain a constant damping ratio over the entire operating temperature range of −65°F. to +175°F.

This new Honeywell Rate Gyro is designed expressly for flight control of missiles and flight instrumentation in missiles and aircraft where severe ambient conditions prevail . . . and at the same time where low threshold, minimum hysteresis, excellent linearity, high natural frequency and ruggedness are essential.

Honeywell inertial components and engineering experience are available to assist in the solution of your Gyro system problems. Write for Bulletin JRT . . . Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston 35, Mass.

Honeywell

Military Products Group

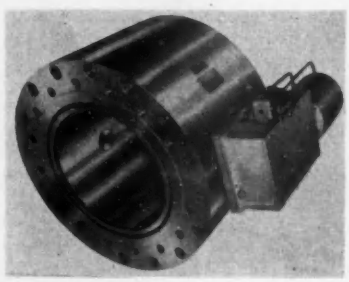
DESCRIPTIVE DATA

- **EXCELLENT LINEARITY:** 0.25 % of full scale.
- **LOW HYSTERESIS:** Less than 0.1 % of full scale.
- **LOW THRESHOLD:** Less than 0.01 degree/second.
- **MICROSYN PICKOFF:** Variable reluctance type providing infinite resolution and high signal-to-noise ratio.
- **FULL SCALE RATE:** Up to 1000 degree/second.
- **FULL SCALE OUTPUT:** Up to 12 volts.
- **RUGGED:** Withstands 100 G shock.
- **VIBRATION:** Withstands 15 G to 2000 cps.
- **SIZE:** 2 7/64" diameter 4 5/16" long.
- **WEIGHT:** 2 lbs.

NEW PRODUCTS

model is rated at 60 psi. They are designed for general use with water, air, steam, inert gases, and many semi-corrosive media, are priced at $6.50, and are stocked for immediate delivery. – Valcor Engineering Corp., Kenilworth, N. J.

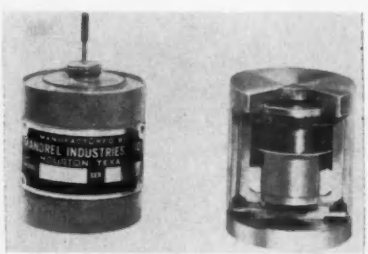
Circle No. 22 on reply card



ZERO LEAKAGE

A new line of large-capacity ball valves features zero leakage and zero-pressure drop. Pictured is a 16-in. model for use in a 24-in. liquid oxygen line. Its actuator operates on 120 psig nitrogen gas or air. Other bore sizes, from 2 in. to 24 in., are available. Bubble-tight performance is claimed, even at pressures as high as 500 psi.– The Vickery Co., Los Angeles, Calif.

Circle No. 23 on reply card

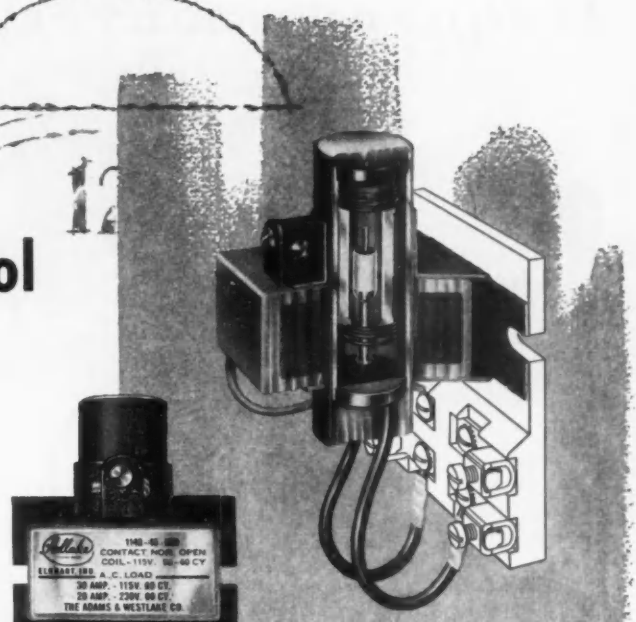


LINEAR FORCE MOTOR

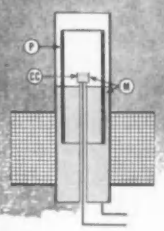
A moving coil device, the Dynastroke Linear Force Motor, features strokes to 0.10 in. and force outputs to 2 lb. Standard coil resistances range from 200 to 4,000 ohms, with resonant frequencies from 10 to 100 cps. Rugged construction and frictionless spring suspensions assure permanent accuracies within 0.1 percent. Less than 2 in. long and $1\frac{5}{8}$ in. in diam, the unit operates over a wide temperature range. Typical applications include force balances, pressure measurements, and valve actuators.–Mandrel Industries, Inc., Houston, Tex.

Circle No. 24 on reply card

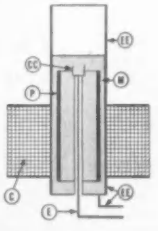
When You Need Reliable Control Of Timed Operations



The "Mighty Midget"
Adlake No. 1140
Plunger-Type Relay
Normally Open • Quick Acting



DE-ENERGIZED
Plunger P is floating in mercury M. External circuit is open because main body of mercury M is below lip of ceramic cup CC.



ENERGIZED
Coil C pulls plunger P down into mercury M. Mercury thus displaced completely covers ceramic cup CC filled with mercury. This establishes mercury-to-mercury contact between electrodes E and EE.

You Need

Adlake

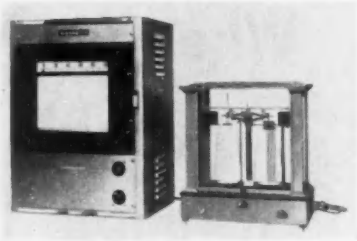
mercury-to-mercury relays

List what you like and don't like in a switch, then see how Adlake meets your need:

- **Immune to vibration**
- **Perfect snap-action—no burning, pitting or sticking**
- **No intrusion of dust, dirt or moisture—hermetically sealed at the factory**
- **Time delay characteristics fixed and non-adjustable**
- **Quiet. Chatterless. Require no maintenance whatever.**

Our engineers will gladly help you with your control problems. No obligation. Just write the original and largest maker of plunger-type relays—THE ADAMS & WESTLAKE COMPANY, 1181 N. Michigan, Elkhart, Ind. • New York • Chicago

RESEARCH, TEST & DEVELOPMENT



RECORDING BALANCE

Completely new, this automatic analytical balance recorder shows instantaneous weight and rate-of-weight change. Probable applications include thermogravimetric analysis, and investigation of evaporation, absorption, corrosion, oxidation, decomposition, and other reactions in which weight-vs.-time or weight-vs.-temperature is a significant factor. Capacity is 200 grams. An 11-in. strip chart represents a weight change of 110 mg. Accuracy and readability are within plus or minus 1/10 mg.—Wm. Ainsworth & Sons, Inc., Denver, Colo.

Circle No. 25 on reply card

MISSILE CG LOCATER

Heart of the new Mark V Weight and CG Locater is a high-accuracy, high-resolution electromechanical force beam, originally developed for measuring forces on wind-tunnel models. Designed for production testing of missiles, the locater is 8 ft long, has a capacity of 1,100 lb, and provides digital display of total weight and differential. Guaranteed accuracy of total weight is within 0.15 lb; location of cg, within 0.01 in. Accessory equipment can be provided for applications

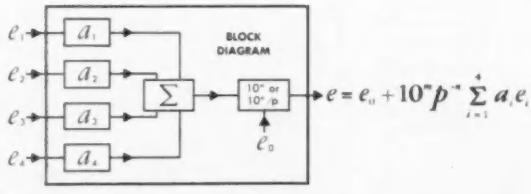
analog computor with a NEW TWIST

Just twist the knob... decade settings simplify precise parameter programming

In the all-new Philbrick Model K5-U Universal Linear Operator, decade settings replace the usual computing potentiometers to simplify precise parameter programming. Easy to interconnect and use, Model K5-U embodies a variety of operations in one compact, chopper-stabilized unit. This fundamental building block of a general purpose analog computing system permits the analog computor user to extend his design and analysis facilities at reasonable cost.

The Model K5-U accepts up to four voltages and multiplies each by a constant, settable by decade switches to any positive or negative value between 0 and 11.10 in increments of 0.01. These weighted inputs are added together and the sum is then operated on in one of two general ways.

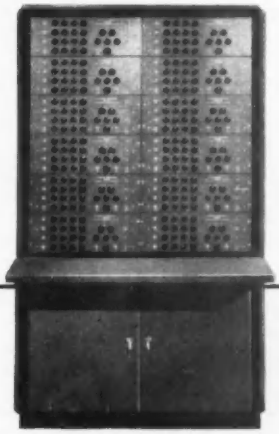
1. The sum may be multiplied by 0, 1, 10, 100 or 1000 and then have added to it a positive or negative index voltage, adjustable from 0 to 50.0 volts in steps of 0.1 volt.
2. The sum may be integrated using any of a wide range of available speeds, viz., 1, 10, 100 or 1000 radians per second. The output voltage may be held at any time, or it may be reset to an initial value which is determined by the index voltage decade setting. The SET-RUN-HOLD modes may be controlled either remotely or manually on the front panel.



Write to George A. Philbrick Researches, Inc., 230 Congress St., Boston 10, Mass., for the name of the PHILBRICK representative in your area and Technical Bulletin CE1

GEORGE A.
PHILBRICK
RESEARCHES, INC.
230 Congress Street, Boston 10, Massachusetts

- ***Easy to read three-digit decade settings*** — precise adjustment of parameters now possible even during computation.
- ***"Pot-setting" is outmoded*** — time-consuming calibration voltage measurements are eliminated.
- ***Extravagant servo-setting is surpassed*** — simply "read it on the dials" to three figures.
- ***Additional inverting amplifiers are unnecessary*** — individual inputs may be added, subtracted, or removed by the flick of a switch.
- ***Choose your time scale*** — continuous real-time computing, high-speed repetitive operation, and "single-shot" solutions are *all* inherent.
- ***Versatile linear building block*** — Summing Amplifier, Integrating Amplifier, Inverting Amplifier, Initial Conditions, Set-Run-Hold Relays are all available at your fingertips.
- ***Mounting*** — occupies 7" vertically in standard relay rack or enclosure.



Model K5-U retains the convenience, economy and versatility of modular assembly.

NEW PRODUCTS

requiring lateral cg and/or cg location with respect to thrust axis.—Dynametrics Corp., Burlington, Mass.

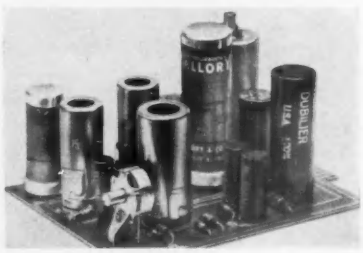
Circle No. 26 on reply card

LOW-COST INDICATOR

This low-cost, direct-reading temperature indicator, Model TB102, is designed for measuring temperatures in hard-to-get-at locations, e.g., the interior of large electronic equipment. Essentially a precision Wheatstone bridge, it uses standard copper resistors as sensing elements. Variation in resistance is an accurate measure of temperature, which is read directly on the balance dial. The TB102 has three separate channels and covers a number of temperature ranges to suit specific requirements.—Dynamic Development Co., Westbury, N. Y.

Circle No. 27 on reply card

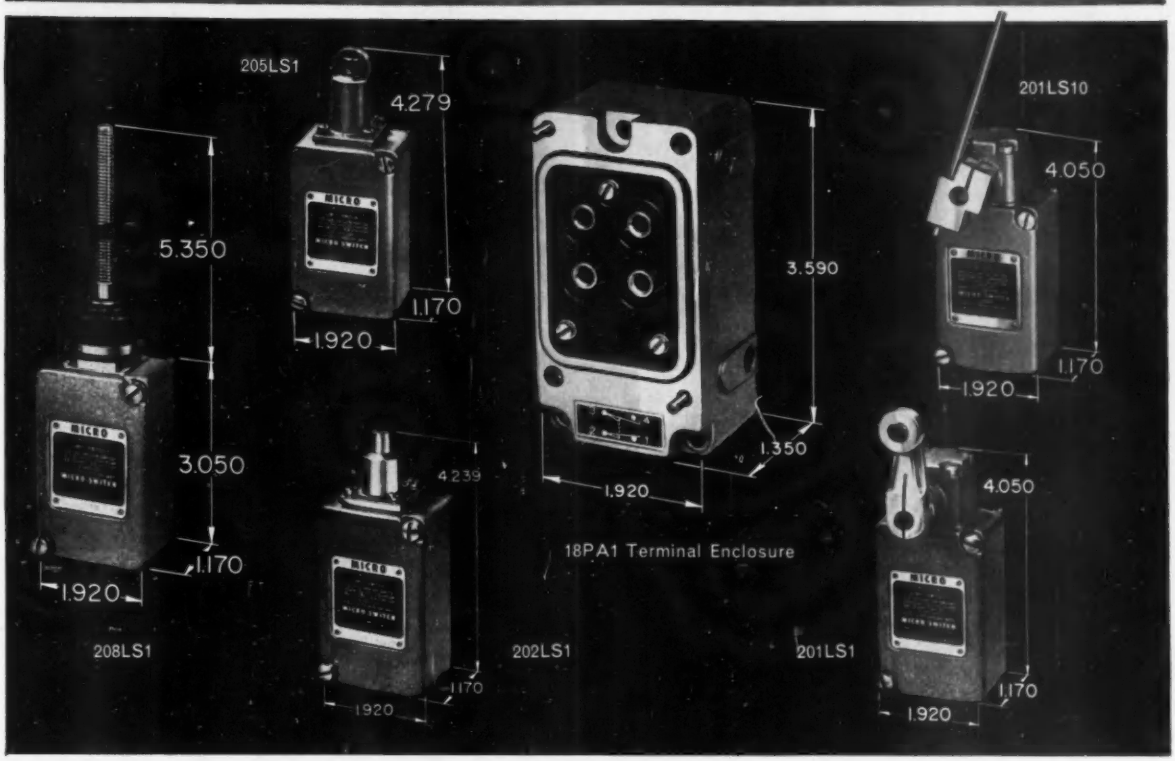
COMPONENT PARTS



SERVO PREAMP

Mounted on a printed circuit chassis measuring 4.5 in. by 6 in., the Model DLA-10 servo preamplifier provides an adjustable voltage gain up to 10,000, including rate network losses. With

MICRO SWITCH Precision Switches



This NEW MICRO SWITCH "Plug-in Limit" Switch cuts downtime to 20 seconds

The new MICRO SWITCH "Plug-in Limit" Switch plugs in like a radio tube and can be replaced in seconds.

It offers all the features of rugged construction and precision long-life operation, so necessary in a limit switch. The assembly of the terminal block and switching unit comprise a complete switch thoroughly sealed against cutting oils, chips, dirt and dust. The "200LS" series switches meet NEMA standards.

The switch enclosure, including all moving mechanical and electrical parts, is plugged into the terminal block, precisely positioned by means of dowel pins. Under normal conditions the terminal enclosure need never be removed from the machine.

18PA1 Terminal Enclosure—This enclosure is common to all actuator assemblies in the "200LS" series. Can be mounted from front, back or either side. All switch enclosures illustrated above fit this terminal enclosure. Two No. 10 captive screws secure the two enclosures together.

208LS1 Coil Spring Actuator—flexible spring actuator for multi-direction operating motion.

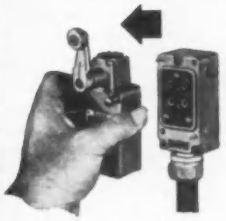
205LS1 Roller Plunger Actuator—adjustable at 90° angles.

202LS1 Push Plunger Actuator—for in-line actuating motion.

201LS10 Rod Actuator—provides light actuating force. See adjustability details under 201LS1 below.

201LS1 Roller Arm Actuator—field adjustable for actuation in either clockwise or counter-clockwise, or in both directions. Arm is adjustable through 360° Actuating head can be faced in any of four directions.

For details of the "200LS" series, send for Bulletin No. 20.



PULL OUT

PLUG IN

The two-word name "MICRO SWITCH" is NOT a generic term. It is the name of a division of Minneapolis-Honeywell Regulator Company.

MICRO SWITCH

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

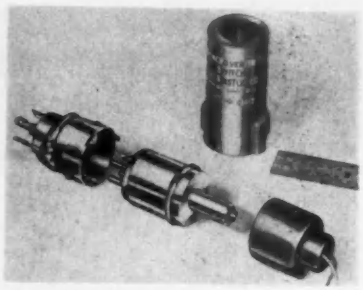
In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS

First in Precision Switching

NEW PRODUCTS

the proper output stage and actuator, the unit has less than 0.02 percent servo nulling error. It is part of a complete line of modular, plug-in, analog and digital control system components.—Electro Precision Corp., Arkadelphia, Ark.

Circle No. 28 on reply card



LOW-NOISE CHOPPER

Well-suited for use in chopper stabilized dc amplifiers, where thermal stability and low noise are important, this miniature chopper completely shields the coil from the contact assembly. Modular construction permits coil interchange to optimize thermal dissipation and minimize power drive at preselected frequencies between 0 and 700 cps. Nominal thermal stability is within 2 microvolts.—The Bristol Co., Waterbury, Conn.

Circle No. 29 on reply card

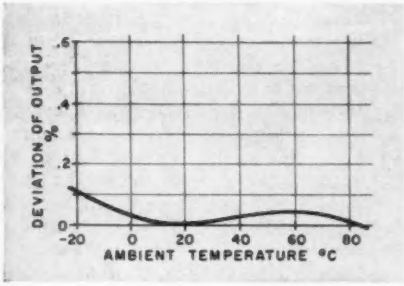
TWO-SPEED GEARHEAD

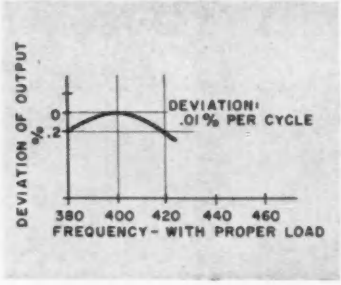
Pictured is a precision servomotor gearhead that changes speed ratios whenever dc voltage is applied to, or removed from, an actuating solenoid. Designed for integration with sizes 11, 14, or 18 motors, it requires only 0.008 oz-in. of starting torque and will operate with 12 oz-in. of load torque.

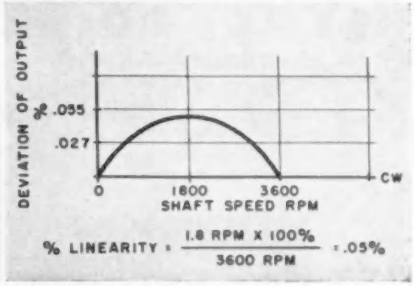
NEW KEARFOTT TACHOMETERS:

KEARFOTT SIZE 11 AND SIZE 15
INTEGRATING TACHOMETERS
ACTUAL SIZE

. . . provide precise integration under all conditions







TEMPERATURE

Variations of output, due to temperature changes, are minimized by Kearfott's precise unit temperatures control and/or compensation.

FREQUENCY

Variations due to frequency changes are held to .01% per cycle with appropriate loading.

SPEED

Minimum deviation of output from mean value due to speed is characteristic of these precision tachometers.

Kearfott Tachometers are ideally suited for applications in aircraft, missiles, and other equipment requiring precise integration. They are compact and light in weight. They offer excellent environmental resistance due to all stainless steel construction. Kearfott's unique design eliminates the need for thermostatic temperature control. Units available to operate under high temperature (200°C.), high vibration (500 cps) and shock (10 G's).

GENERATOR CHARACTERISTICS

MODEL	VOLTS OUTPUT PER 1000 RPM	LINEARITY TO 3600 RPM	EXCITATION AT 400 CPS
Size 11 R860-25	2.75	0.1%	115V
Size 11 R862-22	2.75	0.1%	115V
Size 15 T816-25	2.9	0.05%	115V

SERVO MOTOR CHARACTERISTICS

MODEL	NO LOAD SPEED	STALL TORQUE
Size 11 R860-25	5500 RPM	0.55 in. oz.
*Size 11 R862-22	4500 RPM	0.5 in. oz.
Size 15 T816-25	4500 RPM	0.4 in. oz.

**Drag Cup Motor—Maximum starting voltage, 1 volt.*

Send for data sheet on Kearfott Tachometers and other Kearfott Components and Systems.

ENGINEERS:
Challenging opportunities at Kearfott in advanced component and systems development.

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
Sales and Engineering Offices: 1378 Main Avenue, Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Illinois.
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West Coast Office: 253 N. Vinedo Avenue, Pasadena, California.

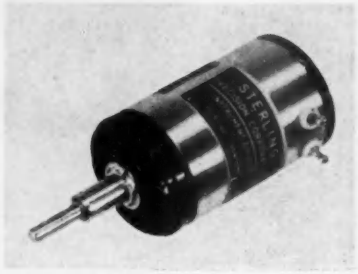
Kearfott

GENERAL PRECISION EQUIPMENT CORPORATION GPE

NEW PRODUCTS

Speed ratios in the size 14 unit shown here are on the order of 1,800:1 de-energized and 36,000:1 energized. Primary applications are in positioning computing mechanisms which require fast approaches but slower zeroing or synchronizing action.—Bowmar Instrument Corp., Fort Wayne, Ind.

Circle No. 30 on reply card



SAVES POWER

A new line of reverse-acting electromagnetic clutches and clutch brakes differs from conventional types in that input and output shafts are coupled when the coil is de-energized. Energizing the coil uncouples the shafts and applies the brake to the output shaft if required. In many applications, this results in a conservation of power. Coupling faces may be supplied flat or with crown teeth, providing a wide range of torque transmission. Braking surfaces are flat and are rated for a minimum torque of 8 oz.-in.—Sterling Precision Corp., Flushing, N. Y.

Circle No. 31 on reply card

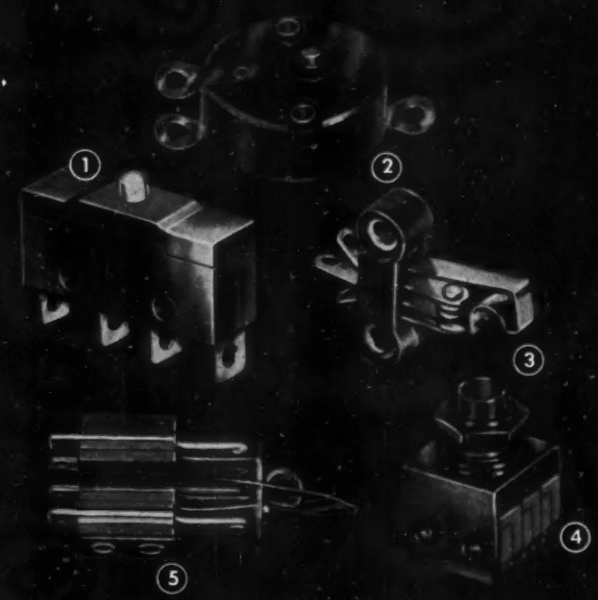
VERSATILE DIODE

A new subminiature silicon junction diode, 1N658, boasts high conductance, fast recovery, high peak inverse voltage, low reverse leakage, and a broad operating temperature range. Designed for computer, communications, military, and general circuit requirements, the new diode will also serve in moderate power applications. Foward voltage drop is said to be under 1 volt at 100 ma, with a 0.3-microsec reverse recovery. Peak inverse voltage is 120 volts, with a reverse leakage of 0.05 micro-amps at minus 50 volts and 25 deg C, and 25 microamps at 150 deg C. The unit will handle an average rectified current of 200 ma and has a power dissipation rating of 0.2 watts.—Radio Receptor Co., Inc., Brooklyn, N. Y.

Circle No. 32 on reply card

why it pays to depend

OFF ON...



1 STANDARD SUBMINIATURE

High capacity—over four times that of most switches its size. Rated at 10 amps at 125 or 250 volts A.C. or 28 volts D.C. Wide range of newly designed actuators . . . or can be adapted to present actuators and mountings. Operating temperature range: —80° to +350°F. Terminal arrangement permits wiring double circuits.

2 NEW TYPE Q SUBMINIATURE

Smallest snap-action switch with a 10 amp—115 volt capacity. Designed for extra vibration resistance and easy installation. Adaptable to automation techniques. Ruggedly built to take up to 100,000 operations at capacity load. Meets a variety of circuit requirements.

3 OPEN BLADE SUBMINIATURE

Use your own housing—even include other components if you desire—with this unique precision switch. Readily adapts to return or set type operation. Actuator may be insulated or extended to meet requirements. Many other combinations are possible.

4 PUSH BUTTON SUBMINIATURE

Three split contact circuits in subminiature size. Only 25/32" long by 35/64" wide by 1 13/64" high. Rated at 10 amps—115 volts A.C. This panel mounted, overtravel plunger-type actuator assembly is believed to be the smallest yet made.

5 OPEN BLADE MULTI-POLE SUBMINIATURE

Recommended for economical and positive control of two circuits. Laminations are secured by two eyelets which provide holes for mounting screws. Available in return or set type with rear or side terminals.

ACRO Subminiature Switches

Compare the ACRO group of Subminiature Switches any way you like—cost, performance, size, capacity, versatility—you'll see why more and more design engineers are specifying ACRO.

These five basic types of subminiature switches offer many development possibilities for your subminiature assemblies . . . from aircraft applications to vending machines. All incorporate the patented rolling spring action for which ACRO Switches are internationally known and respected.

ACRO's modern mass-production techniques and facilities assure lowest possible unit cost . . . even when variations of basic switches are required to meet your specific needs.

Talk over your requirements or possibilities with an ACRO engineer . . . or write for engineering data on any or all of the five subminiature switches shown here.

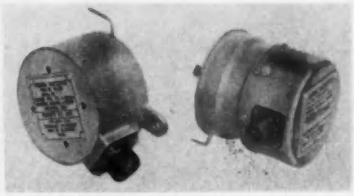
Mr. Controls®

Robertshaw-Fulton CONTROLS COMPANY

ACRO DIVISION Dept. 144, Columbus 16, Ohio

In Canada: Robertshaw-Fulton Controls (Canada) Ltd., Toronto

NEW PRODUCTS



PRECISION POTS

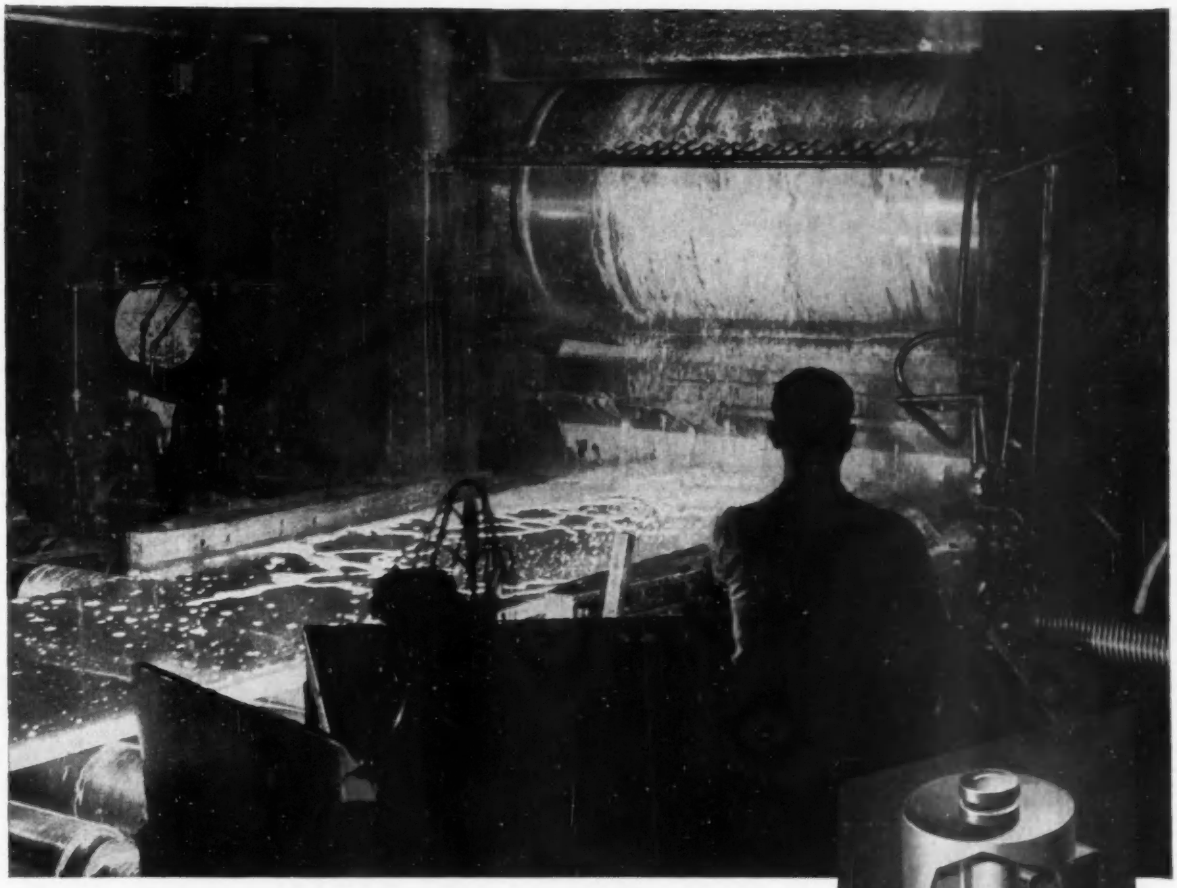
This unique pair of precision potentiometers has been designed to actuate a hydraulic servo on a supersonic bomber. One consists of a nonlinear control transmitter using a 10:1 gearing system at the shaft input and generating a nonlinear curve with a slope ratio of 80:1, either side of center. The other, a position transmitter, uses three parallel linear elements and supplies a feedback signal proportional to position.—Technology Instrument Corp. of California, North Hollywood, Calif.

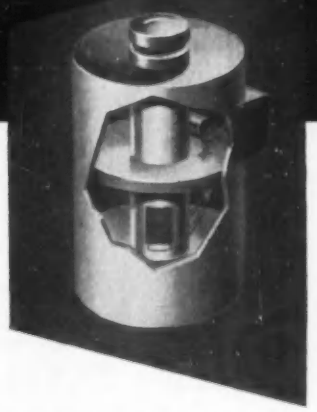
Circle No. 33 on reply card

VARIABLE TRANSFORMER

Pictured is the first of a new line of variable transformers, the Model VT1R5. The unit will deliver 1.5 amp at any brush setting, even at full overvoltage. Features include a pigtail shunt that carries the current from the brush to a large copper graphite slip ring; a springlike brush arm that provides its own contact pressure; a ceramic hub that aligns the brush arm and provides 3,000-vac insulation; and an internal stop that protects the brush and brush arm. The dial itself is reversible, permitting direct reading of the output voltage for either line or overvoltage connection. One side is calibrated 0-120 volts, the opposite side 0-132 volts.—Ohmite Mfg. Co., Skokie, Ill.

Circle No. 34 on reply card





A giant "squeeze"—measured and controlled by B-L-H Load Cells

Despite the tremendous forces unleashed in a rolling mill operation, the actual pressure exerted by the giant rollers can be measured with high precision by built-in B-L-H SR-4® Load Cells. These electronic transducers give the operator exact load readings, enabling him to roll sheets to just the proper thickness every time.

B-L-H transducers will measure any forces involving tension, compression, torque, etc. With appropriate instrumentation, they can also determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. Long-term accuracy is within ±1/10%, repeatability within ±1/20%. The type and number of applications are virtually unlimited.

SR-4® Load Cells have capacities ranging from 50 to 200,000 lb. Loads on the cells are converted to proportional voltage—permit the instruments for reading or recording changes to be located at any remote point.

For more information on these precision load cells, have us send one of our field men around to see you, without obligation. And write to Dept. 6-D for a copy of Bulletin 4302.

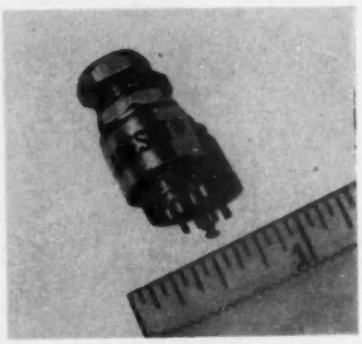
BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

NEW PRODUCTS

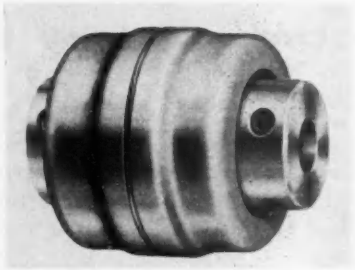


HIGH THERMAL STABILITY

A new line of microminiature, precision wire-wound pots is said to provide greater stability under temperature cycling than other types of comparable size. The units will dissipate 2 watts at 60 deg C, and are available in nine resistance values between 100 and 25,000 ohms. Nominal mechanical rotation is 330 deg; resistance tolerance is plus or minus 10 percent; and linearity is plus or minus 5 percent.—Ace Electronics Associates, Inc., Somerville, Mass.

Circle No. 35 on reply card

ACCESSORIES & MATERIALS



FLEXIBLE COUPLINGS

This new line of flexible couplings permits angular misalignment up to 5 deg parallel offset to as much as 0.010 in., and axial end-play up to 0.090 in. They will transmit torques up to 150 oz-in., allow speeds up to 10,000 rpm, minimize backlash, and operate over a wide temperature range. Overall diameter is 1.078 in., with hubs bored to take $\frac{3}{16}$-, $\frac{1}{4}$-, $\frac{5}{16}$-, or $\frac{3}{8}$-in. shafts or any combination of these sizes.—Metron Instrument Co., Denver, Colo.

Circle No. 36 on reply card

DELCO HIGH POWER TRANSISTORS are made from

In the center of the quartz housing, a germanium crystal is being grown. A "perfect crystal lattice," it will be cut into wafers 3/10ths of an inch square and less than 1/100th of an inch thick to become the heart of Delco High Power transistors.

GERMANIUM

because it alone combines these 5 advantages:

Lower saturation resistance—Germanium gives Delco High Power transistors a typical saturation resistance of only *3/100ths* of an ohm. No other present material offers this characteristic, which permits efficient high-power switching and amplification from a 12- or 24-volt power supply.

Higher current gain—Gain with germanium is not only higher but is more linear with current.

Lower distortion—In many applications, distortion requirements can be satisfied only with germanium transistors.

Lower thermal gradient—As far as deliverable power of present devices is concerned, germanium meets the need and, in addition, provides a thermal gradient of only 1.2° C/watt.

Greater economy—More power per dollar.

DELCO RADIO

Division of General Motors, Kokomo, Indiana

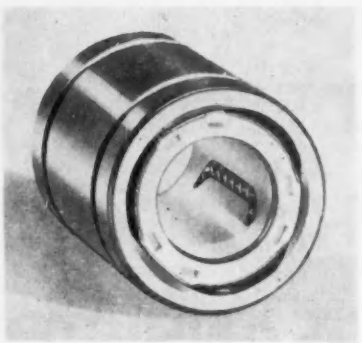
BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel.: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel.: Exbrook 3-1465

Examine Delco High Power germanium transistors and see how practical it is to go ahead with your plans now. For high current applications there is no better material than germanium, or Delco Radio would be using it. All Delco High Power transistors are produced in volume; all are normalized to retain their fine performance and uniformity regardless of age. Write for engineering data and/or application assistance.

NEW PRODUCTS



HIGH SENSITIVITY

Shown is a new super-sensitive ball bushing for instrument and control applications. Designated INST-4812, it has a bore diameter of 0.2500, an outside diameter of 0.5000, and a length of 0.750 in. Rolling load rating is 13 lb; static load, 22 lb. Factory inspection requires that the bushing roll down a shaft at a 20-min angle, but by a new way of using it, the maker claims it is possible to cut this angle to 1 min or less.–Thomson Industries, Inc., Manhasset, N. Y.

Circle No. 37 on reply card

LIGHTWEIGHT FAN

The Propimax-2 cooling fan, recently introduced, delivers 120 cfm free air, yet weighs only 6 oz and measures 3 in. in diameter. It is available for operation on 115 vac, single-phase, or 220 vac, 3-phase, 400 cps; its standard constant-speed motor turns at 20,000 rpm. An altivar design is also available for maintaining cooling efficiency at changing altitudes–Rotron Mfg. Co., Inc., Woodstock, N. Y.

Circle No. 38 on reply card

TUBE WITH A ZIPPER

A new laminated type of flexible tubing with a patented slide fastener is now available for harness applications

Progress in Leadership...

SLAVE-ROBOTS WITH A SENSE OF "FEEL"

The RADIOACTIVITY levels in modern nuclear science call for the development of master-slave manipulators and slave-robots.

At Argonne, the Remote Control Engineering Division is designing a mobile robot for nuclear engineering operations beyond the capabilities of existing master-slave manipulators. The robot can be maneuvered as commanded. Its "force reflecting" servo-mechanisms will transmit the "feel" of the robot's hands to the operator. Force multiplication may be used to preserve a sense of "feel" in heavy duty manipulators. Observing the slave through stereo TV, the operator can carry out the precise remote manipulation required in nuclear work.

The development of advanced hydraulic and electrical designs of such systems is typical of the challenging problems associated with basic research and development at Argonne.

Inquiries Invited:

M.E.'s and E.E.'s for electro-mechanical, mechanisms, radio telemetering and stereo TV development work. E.E. familiar with high voltage switch gear, high voltage rectifier sets, rotating machinery, pulse transformers and techniques of high energy transient work. E.E. with cyclotron experience. Physicist for study of irradiation damage on electro-mechanical systems and optical materials. Physicist with electronic background for work in nondestructive testing.

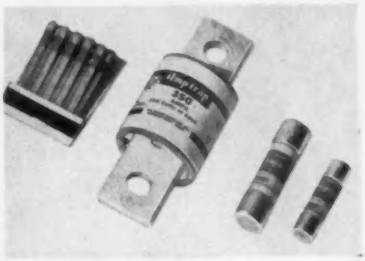
Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under contract with the United States Atomic Energy Commission

Professional Personnel Office
P. O. Box 299-A3, Lemont, Ill.

NEW PRODUCTS

requiring shielding. This new Zippertubing is made of a plastic saturated Fiberglas backing laminated to aluminum, lead, or magnetic foil, weighs much less than conventional shielded harness, and is readily installed.—The Zippertubing Co., Los Angeles., Calif.

Circle No. 39 on reply card



FAST PROTECTION

Called the Form 101, this new circuit protective device features high interrupting capacity and current limiting at about four times its normal rating. A wide variety of capacities and sizes are available for 65-, 130-, and 250-volt service. Depending on rating, units will continuously carry from 1 to 10,000 amp of normal current. They limit on overload but blow instantly on short circuit, thereby avoiding damage to components.—Chase-Shawmut Co., Newburyport, Mass.

Circle No. 40 on reply card

IMPROVED PLASTIC

According to its manufacturer, Phenolite Grade G-11, a new glass base epoxy material, offers a better high-temperature resistance than other epoxy grades. Insulation resistance and dielectric strength is also superior to other glass base grades. Other features include high impact strength, low water absorption, and dimensional stability as a copper-clad material.—National Vulcanized Fibre Co., Wilmington, Del.

Circle No. 41 on reply card

FINE MAGNETIC WIRES

Two new magnetic wires, Thermester-L and Temprite, are available in gauges as fine as 50 AWG. Thermester-L, a recent development, has a maximum operating temperature of 155 deg C; the Temprite (Teflon) type will serve at temperatures as high as 250 deg. C.—Hitemp Wires, Inc., Westbury, N. Y.

Circle No. 42 on reply card

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CONTROL ENGINEERING
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(100) FLUID POWER DRIVES. The Oilgear Co. Bulletin 10600, 32 pp. An excellent presentation covering the operation and application of the company's versatile "Any-Speed" fluid drives. Includes numerous performance curves relating speed and torque to either time or load.

(101) INSTRUMENTATION CABLES. Rome Cable Corp. Bulletin RCD-400, 8 pp. Describes a variety of insulated cables for telemetering, data recording, circuit testing, and computer applications. Provides tables of military and manufacturer's specs, and capacitance test values.

(102) SCANNING SWITCH. Applied Science Corp. of Princeton. Bulletin, 8 pp. Specifications and application data on the company's Type AU high-speed sampling switch. Accessories include driving sources, gear reducers, and switch modules.

(103) THERMOCOUPLES. Aero Research Instrument Co., Inc. Data Sheet No. 385, 2 pp. Offers data on completely enclosed, electrically insulated, fast-response thermocouples for temperatures ranging from minus 320 to 1,900 deg. F. Specs cover connector types and fittings.

(104) PRECISION POTS. Analogue Controls, Inc. Catalog No. P103, 12 pp. Summarizes specifications of various models and defines loading, trimming, linearity (independent, zero-based, or terminal), and linearity testing. Contains dimension drawings and circuit diagrams.

(105) DIGITAL CONTROL. Anatran Div. of Endevco Corp. Technical bulletin, 4 pp. Called "Digitometry—A Concept of Digital Control and Indication", this bulletin describes five new components for use as digital actuators and feedback devices in instrumentation and servo systems.

(106) SWITCH APPLICATIONS. Micro Switch Div. of Minneapolis-Honeywell Regulator Co. "Uses Unlimited", Vol. 11, No. 2, 8 pp. Cites features of some new switches and describes a number of typical applications, including an indexing machine, an elevator control, and a submersible pump.

(107) PAPER MILL CONTROLS. Detectron, Inc. Brochure, 8 pp. Discusses equipment for dynamic quality control in the paper industry. Functions include inspection, detection, classification, counting, signaling, and controlling. Shows console and wall-mounted units.

(108) PROGRAMMED POWER. Electronic Measurements Co., Inc. Bulletin 765, 8 pp. Shows how to use power supplies in automation. Applications include a remotely controlled dc source, a direct motion-to-voltage converter, and a programming-power source.

(109) SEMICONDUCTOR APPLICATION. Hoffman Electronics Corp. Vol. 1, No. 1, 4 pp. First in a new series of semiconductor application bulletins, it illustrates how nonlinear characteristics of silicon diodes make them suitable for protecting measuring instruments.

(110) POWER ACTUATORS. Conoflow Corp. Bulletin B-50-3, 12 pp. Describes the company's complete line of pneumatically positioned power actuators for throttling control service. Applications cover control of pumps, valves, speed-changers, rheostats, flow regulators, etc.

(111) COMPUTER OPERATION. Bendix Computer Div. Bulletin, 6 pp. Features a description of the programming techniques used with the Bendix G-15 general-purpose digital computer. Also covers specifications and some accessories.

(112) GAS ANALYZER. Mine Safety

Appliance Co. Bulletin No. 1703-4, 8 pp. Presents three basic systems using various component combinations, to illustrate the flexibility of the Model F Combustible Gas Analyzer. Discusses operating principles and special features.

(113) SIZE 11 SERVOMOTOR. Helipot Corp. Data Sheet 912, 2 pp. Offers a detailed description of a new size-11 servomotor with adjustable velocity damping. Includes cutaway drawing, specifications, and torque-speed curve.

(114) POT LOADING ERROR. Technology Instrument Corp. Bulletin No. 10, 4 pp. Provides a number of curves illustrating the magnitude of error resulting from loading effects on several nonlinear function potentiometers. Explains winding procedure used for compensation.

(115) TRANSISTORIZED POWER. Kepco Laboratories, Inc. Condensed Brochure B581, 8 pp. Describes a complete line of voltage regulated power supplies, including transistorized, magnetic, and vacuum-tube types. Tabulates all important characteristics.

(116) INFRARED APPLICATION. Beckman/Process Instruments Div. Data Sheet IR-4201, 4 pp. Uses flow diagrams to illustrate three important areas of sulfur dioxide analysis by infrared techniques: sulfur recovery from petroleum sour gas, controlling reaction velocity in sulfuric acid plants, and monitoring stack gases.

(117) TEMPERATURE SYSTEMS. Minneapolis-Honeywell Regulator Co. Catalog C-60-2, 58 pp. Covers a complete line of filled thermal systems for indicating, recording, and control. Electric and pneumatic instruments, various combinations and options, are described.

(118) CONVERTS 3-15 PSI TO AC. Fischer & Porter Co. Catalog Sheet 59-100, 2 pp. Explains the operation of a new electromechanical transducer for instantaneously converting 3-15 psi input signals to an ac output. Photo and circuit diagram are included.

(119) ADJUSTABLE RELIEF VALVES. Tuthill Pump Co. Catalog 110. Includes performance curves, dimensions, specifications, etc., covering a line of adjustable, spring-actuated relief valves.

(120) NEW DIGITAL VOLTMETER. Kin-Tel Div. of Cohu Electronics, Inc., Bulletin 19-2, 4 pp. Block and circuit diagrams are used to describe the operation of a new dc digital voltmeter. Last page carries a list of specifications.

(121) INFINITELY VARIABLE SPEED. Graham Transmissions, Inc. Bulletin 550, 12 pp. Describes some new systems for automatic speed control in response to 3-15 psi air signals, 0.5 to 5 ma electric signals, and others.

(122) SYNCHRO LINE. Muirhead & Co. Ltd. Folder, 6 pp. Presents in a series of tables the salient characteristics of the company's synchros, servomotors, resolvers, motor tachometers, and tachometer generators. Touches on test equipment.

(123) SUBMINIATURE RELAYS. Radio Corp. of America. Brochure, 12 pp. Covers a broad range of subminiature relays for missile and other airborne applications. Performance specs are tabulated and a curve shows a typical overload rating.

(124) JET ENGINE TEMPERATURES. Fenwal, Inc. Bulletin MC-153, 4 pp. Illustrates four basic types of thermocouple junctions for use in aircraft gas turbines and related applications. Points out a number of exclusive design features, including the metal-mica "header" and special "fill" method.

(125) PHOTOELECTRIC CONTROLS. Autotron, Inc. Catalog Supplement, 8 pp. Deals with a number of items not covered in the '57 General Catalog. Includes new plug-in mounted photoelectric controls and light sources, new miniature phototube and light source heads with installation diagrams, impact-actuated controls, current-surge-actuated devices, and combined photoelectric and timing controls.

(126) AIR AND HYDRAULIC VALVES. C. B. Hunt & Son, Inc. Bulletin No. 571, 12 pp. Uses over 30 illustrations in describing a complete line of air and hydraulic control valves. Types covered include sliding sleeve, single plunger, "O" type, "B" type, and high-pressure hydraulic valves.

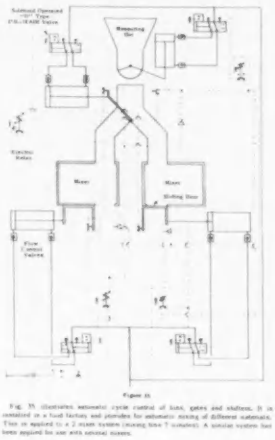
(127) RELIABLE RELAYS. Magnecraft Electric Co. Bulletin, 16 pp. Electrical and mechanical specifications on miniature and subminiature printed circuit relays, 6PDT and power relays, snap action relays, and rectified relays for quiet operation and increased reliability. One section deals with the enclosures available.

(128) MAGNETIC FLOWMETERS. Fischer & Porter Co. Catalog 10D1416, 4 pp. Discusses the principles, operation, and advantages of magnetic flowmeters, emphasizing the special features of F&P models. Lists specifications.

(129) PRESSURE REDUCING VALVES. Jordan Industrial Sales Div., OPW Corp. Bulletin J-160, 6 pp. Offers detailed information on a new line of sliding-gate pressure reducing valves for dead-end shutoff on all fluid services. Contains flow capacity charts, dimension drawings, control ranges, material specs.

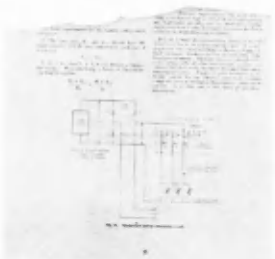
(130) COMPUTER LANGUAGE TRANSLATOR. Electronic Engineering Co. Bulletin B-10M-11-57, 4 pp. Provides some interesting data on the operation and construction of the ZA-100 computer language translator designed to facilitate communication between any of the commonly used computer systems.

APPLICATION LITERATURE



NOTE: To receive any of the following items, the reader should write directly to the manufacturer at the address given.

RESISTANCE THERMOMETERS. Trans-Sonics, Inc., Burlington, Mass. Booklet, 15 pp. Entitled "How to Use Platinum Resistance Thermometers in Temperature Measurement, Telemetry, and Control", this booklet presents the various types and characteristics of specific

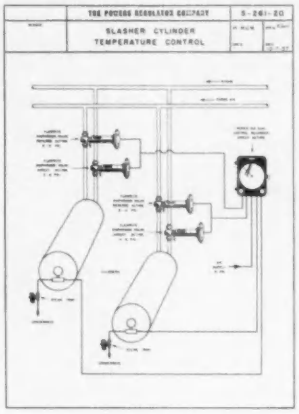


resistance thermometers and describes their applications in a variety of bridge circuits and control systems. Typical of the applications described is a telemetry circuit with a single-pole commutation scheme. The circuit diagram for this arrangement, appearing on page 11, is reproduced above.

BASIC PNEUMATIC CONTROL. Westinghouse Air Brake Co., Industrial Products Div., Wilmerding, Pa. Publication F9-180.00, 28 pp. This handy booklet acquaints the reader with the "systems engineering" approach to the selection and use of pneumatic controls. It presents enough data on the basic pneumatic systems and their advantages to give designers and users a good idea of the value of pneumatics as a practical source of power and control. The circuit shown here, for automatic cycle control of bins, gates, and shifters, might be installed in a food factory. Many other interesting circuits are included.

TEXTILE INDUSTRY CONTROLS. The Powers Regulator Co., 3400 Oakton

APPLICATION LITERATURE

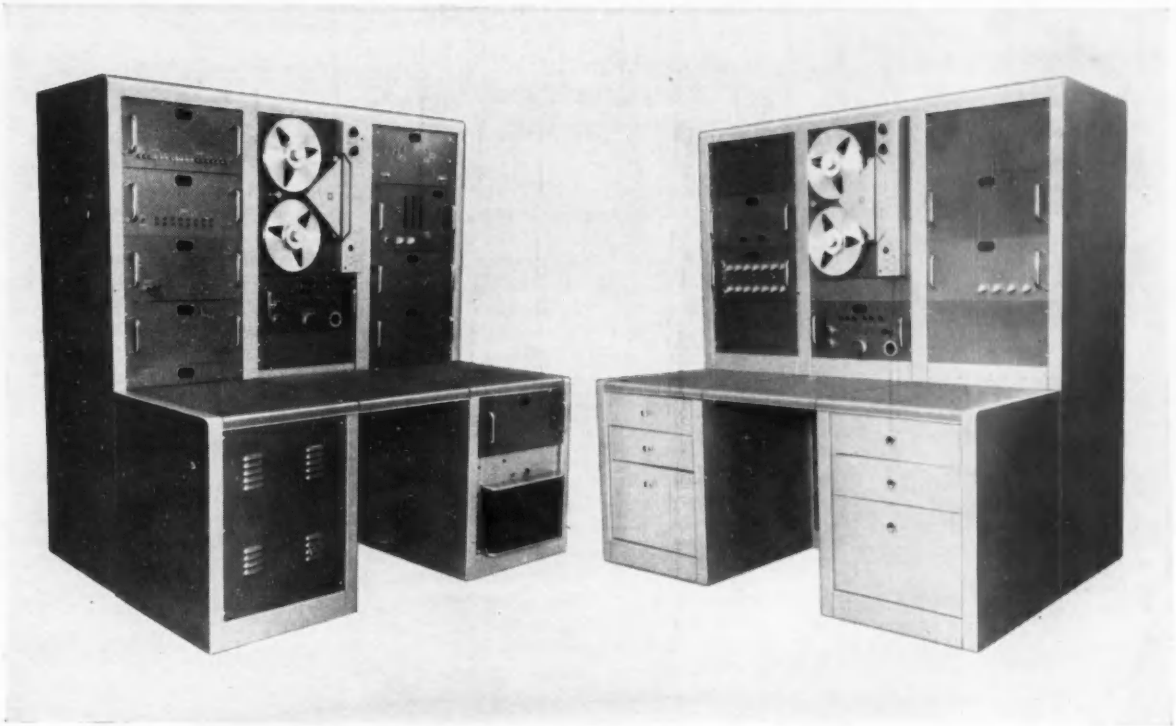


St., Skokie, Ill. "Slasher & Size Room Controls Manual", 18 pp. plus selected bulletins. Designed as an aid to instrument engineers in the textile industry, this new manual describes eight specific slasher-size room control systems ranging in complexity from a simple thermostatic steam trap for condensate lines to the dual slasher cylinder temperature control system shown here. Each system diagram is accompanied by a description of the operation, the advantages of control at particular points, and references to equipment bulletins.

A MANAGEMENT AID. Remington-Rand Univac Div. of Sperry Rand Corp. 315 Fourth Ave., New York 10, N. Y. A 196-page manual, called "A Study for Management—The Univac II Data Automation System", has been prepared to help top management investigate the electronic computer, its capabilities, operation, and applications. The manual begins with a study of the data-processing areas in a typical manufacturing firm, follows with a classified listing of current computer applications. A survey of the types of data-processing systems—manual, key-driven, punched card—and electronic computers rounds out the introductory section.

Selection considerations are covered in the second section. These include choosing the applications, selecting equipment, selecting and training personnel, preparing the computer program, and planning the computer organization. Then came the operations of the Univac system itself and the "what," "why," and "how" of the computer components.

A complete introductory course in Univac programming, suitable for use as a classroom text, is presented in five sections. These describe: 1) process charting, flow charting, and coding; 2) processing internally-stored data; 3) processing externally-stored data; 4) coding technique; and 5) systems design. This fifth section explains the types of computer runs, the meaning of process chart symbols, and the technique of file maintenance.



This is the Honeywell 7000 digital data recorder-transcriber

. . . a high-speed electronic data acquisition and transcribing system for handling up to 100 channels of analog data with conversion to digital form for data processing.

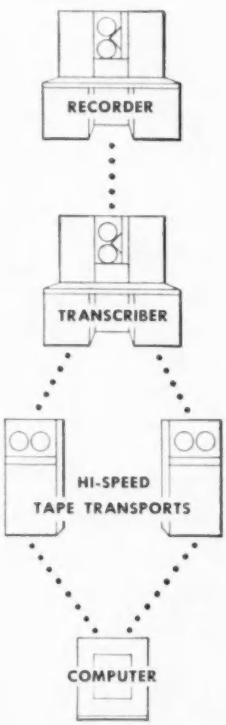
The Honeywell 7000 is a complete multi-channel, high-speed system consisting of two main units—the recorder and the transcriber. The first is located at or near the source of data and produces the first or intermediate tape. The transcriber is generally located at the computer and produces the final tape in the desired computer format.

The Honeywell 7000 is basically designed to perform these functions:

- **Accept input information from multiple transducers.**
- **Scan the input signals sequentially at high speed.**
- **Digitize each input in turn.**
- **Record the digitized values on magnetic tape.**
- **Reproduce the original tape.**
- **Select predetermined portions of the reproduced data.**
- **Rearrange the continuous data into suitable block form for computer input.**
- **Record these blocks of data on another tape for direct entry into the computer.**

The Honeywell 7000 is capable of a scanning rate of 10,000 samples per second. Variations of the basic system are available to adapt the system to meet differing application conditions.

Write for information on the Honeywell 7000 digital data recorder-transcriber . . . and application engineering assistance. MINNEAPOLIS-HONEYWELL, 10721 Hanna Street, Beltsville, Maryland.



The digital data recording-transcribing system is manufactured by Honeywell under agreement with North American Aviation, Inc.

Honeywell

First in Controls

ABSTRACTS

Optimalizing Jet Engine Controls

From "Experimental Investigation of Turbojet-Engine Multiple-Loop Controls for Nonafterburning and Afterburning Modes of Engine Operation" by D. B. Kirsch, L. M. Wenzel, and C. E. Hart, all of the Lewis Flight Propulsion Laboratory, Cleveland, Ohio. Technical Note 4159, National Advisory Committee for Aeronautics, Washington, D. C. January 1958.

The demand for better jet engine performance has emphasized the importance of a fast-acting, variable-area exhaust nozzle as a primary controlling parameter. Such a modulating nozzle speeds thrust increase, gives maximum thrust under various engine conditions, and assures best fuel consumption at different power levels. And it is implicity required in afterburning. This report investigates some of the control modes made possible by manipulation of the two independent engine variables, fuel flow and exhaust-nozzle area.

The controlled variables are rotor speed and turbine discharge temperature. Since both of these are functions of the independent fuel flow and nozzle area, two basic double-loop systems are possible. These are shown in the block diagrams below. In A, rotor speed is controlled by manipulation of the nozzle area, temperature by manipulation of the fuel flow. In B, the parameters are reversed; here speed is controlled by the fuel flow and temperature by the nozzle area. $K_{n/t}$ and $K_{t/n}$ represent adjustable noninteraction crossover gain terms between the forward paths of the control loops.

Results showed that the speed-area, temperature-fuel configuration (diagram A), with no compensation, provided the best performance characteristics. Advantages included simplicity of control and noncritical adjustment of the speed-area gain setting.

On Cascade Control

From "The Design of Cascade Control Systems" by R. L. Day of the ICI Central Engineering Laboratory, Reading, England. Paper presented at a meeting of the Society of Instrument Technology, Manson House, London, Jan. 9, 1958.

Cascade control systems as discussed in this paper are those in which two measured variables are directly related. The primary controller senses the pri-

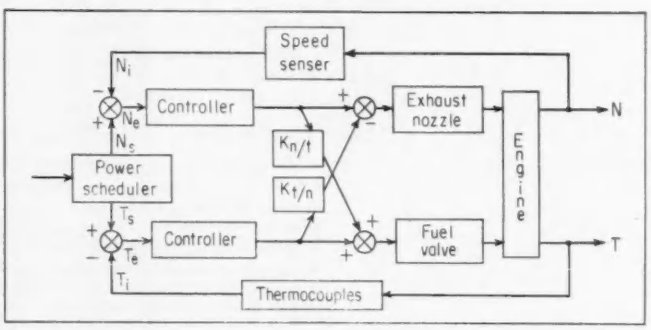


FIG. A

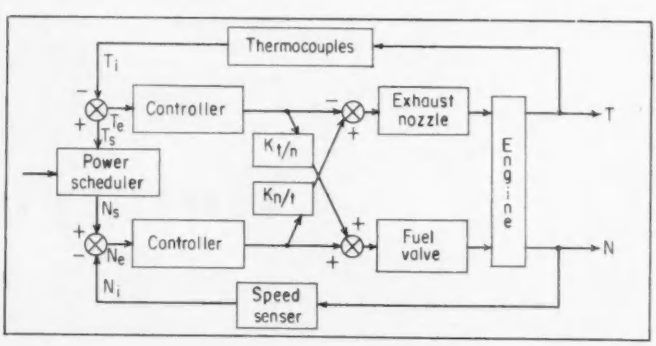
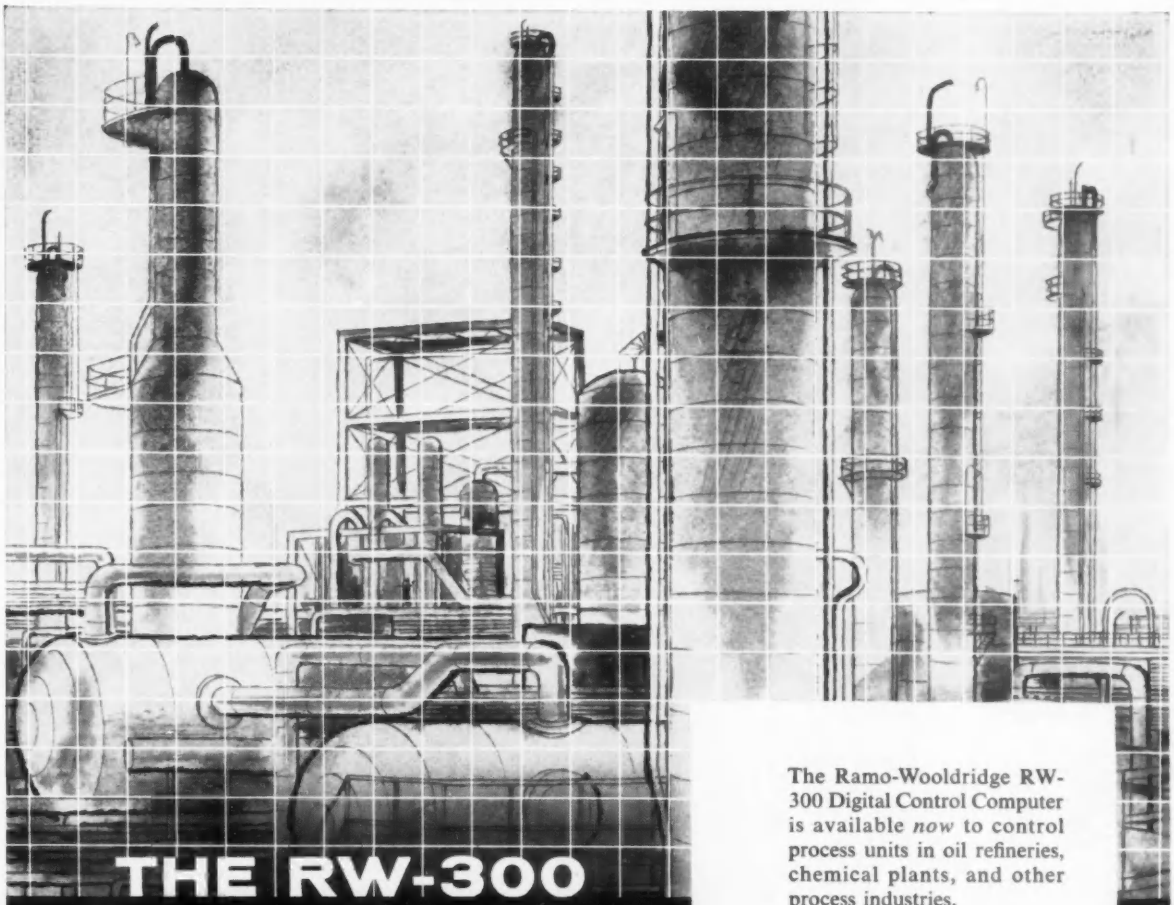


FIG. B



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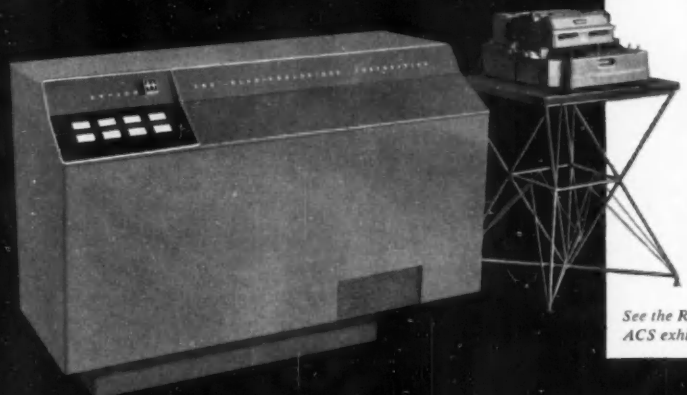

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THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

ABSTRACTS

mary measured condition and has a manually-adjusted set-point; the subsidiary controller senses the subsidiary measured condition and is reset by the output of the primary controller. The output of the subsidiary controller is then applied to the correcting unit.

A brief review of earlier work in this area shows the need for a quantitative treatment on which to base the design of cascade control systems. The author considers the following problems:

- derivation of the cascade frequency-response diagram and hence controller settings
- estimation of control quality in a cascade system, using frequency response data
- advantages of using integral and derivative actions in the subsidiary controller
- limitation of gain in the subsidiary controller to avoid over-ranging of the correcting unit

A vector method is used to calculate the overall frequency response of a cascade control system, and the results are verified by experimental work. Most of this experimental work was performed on the electronic analog computer PANSI, and checked again on an experimental "temperature plant". Control quality is considered in terms of two criteria: a deviation reduction factor (DRF) or the ratio of maximum deviation without control to maximum deviation with control, and the period of the oscillatory response, both following a step disturbance.

Results show that for a step disturbance at the correcting unit the DRF is given approximately by the product of the proportional control factors for the primary and subsidiary loops. For step disturbances after the subsidiary detecting element, the increase in DRF, relative to that for simple control, is of the same order as the reduction in period.

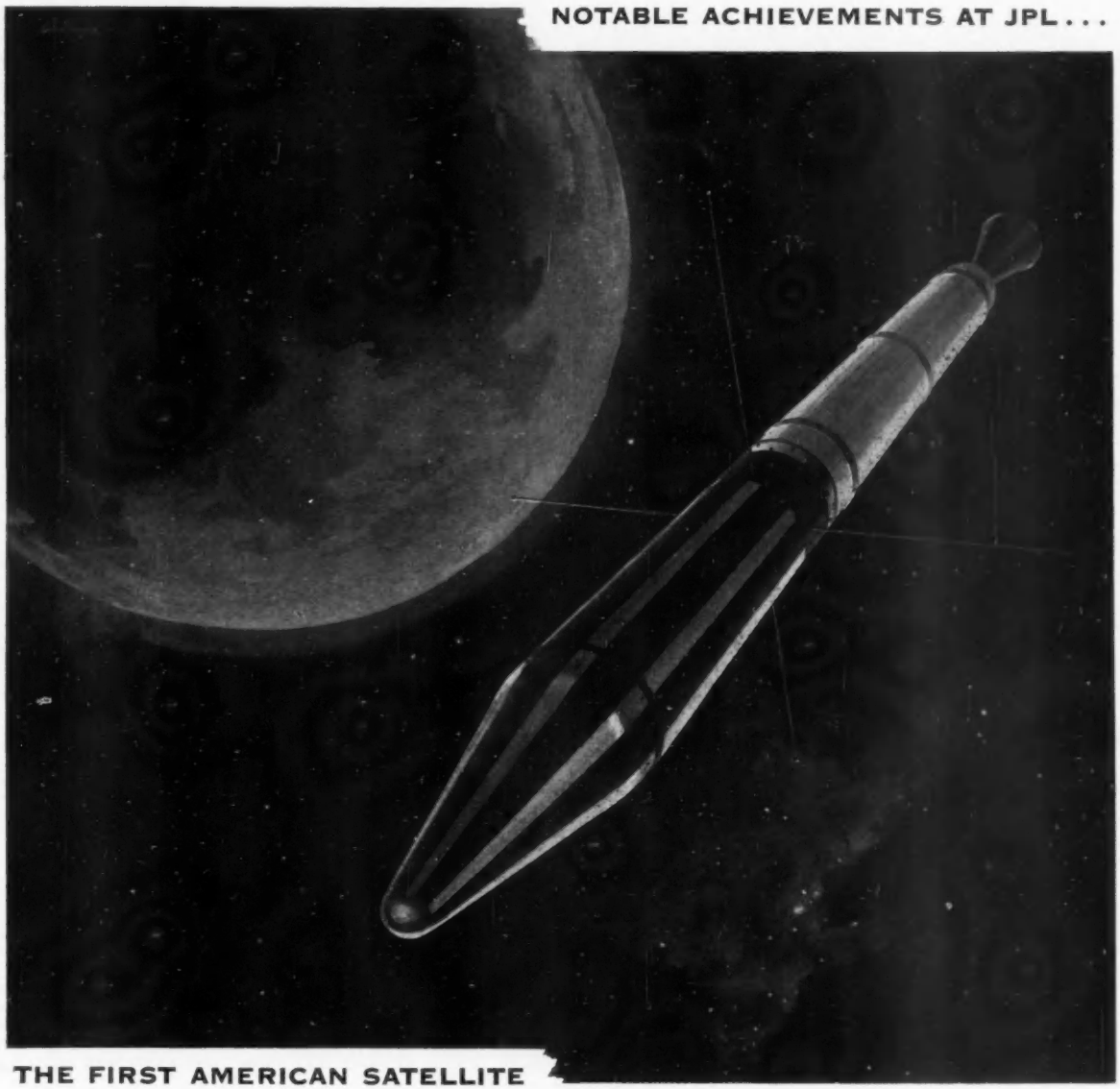
Analysis Conference

The following brief abstracts are taken from the proceedings of the 1957 National Conference on Instrumental Methods of Analysis, sponsored by the Instrument Society of America, Analysis Instrumentation Div., Chicago, Ill., June 13, 14, 15, 1957.

Systematic study . . .

Donald D. DeFord and Robert S. Braman, in a paper entitled "Neutron

NOTABLE ACHIEVEMENTS AT JPL . . .



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ABSTRACTS

Absorptiometry", summarize the results of an investigation into an analytical technique involving the measurement of neutron absorption. This technique is ideal for the determination of boron, and most of the results reported were obtained with boron-containing samples.

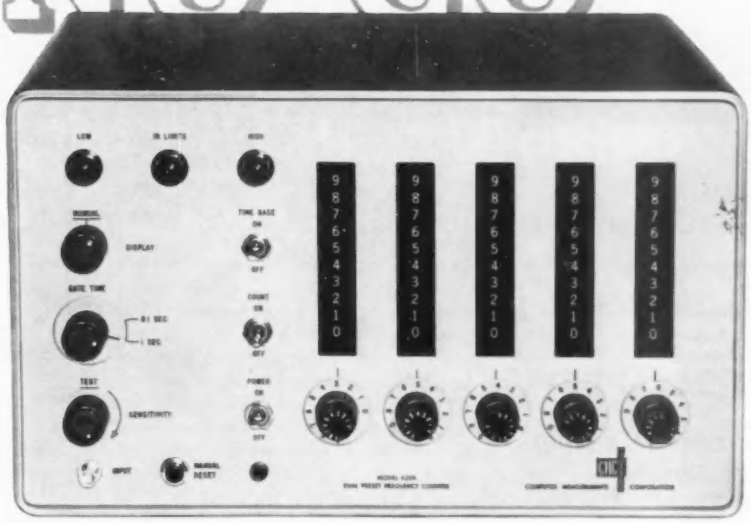
After describing the apparatus used and design considerations involved, the authors set up several equations used to relate counting rate to concentration. Another equation shows the relationship between concentration and the precision attainable. All of these equations involve a blank count rate, N_o, which the authors found to be quite dependent on the type of solvent used to dissolve the sample. Some of the analytical results are tabulated at the end of the paper.

Interference compensation . . .

Entitled "Multicomponent Photoelectric Analysis", this paper by D. J. Troy describes a technique extending the range of double-beam ultraviolet or visible analyzers to complex mixtures. Heretofore these instruments were limited by interference from overlapping of ultraviolet absorption spectra. Troy shows a way to select the optical components of a continuous analyzer to provide complete compensation, even for strong interference. To illustrate he uses an automatic photoelectric analyzer, described in 1955 by L. G. Glasser. Instead of a single optical filter, however, the modified device uses two filters of different wave lengths, one in each beam of the analyzer. Because the analyzer measures intensity ratio, it will not respond to any radiation absorption that is equal in both beams. Thus, if the wave lengths and lengths of the sample cells in each beam are selected so that the interfering substance absorbs equally, the analyzer will not respond to that substance.

The chief advantage of this technique is the long-term stability of both the analyzer span and the interference compensation. Three factors determine these parameters: wave length of radiation, sample cell lengths, and absorbance span of the analyzer. In the model described, absorbance span is uniquely determined by a mechanical light gate. A gas-discharge light source, together with absorption or interference filters, provides wave-length stability. Careful design of the window mounting assures stability of the sample cell lengths.

GO-NO-GO



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CMC *announces the Model 620A*

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INPUT REQUIREMENTS	.05v rms: 10 – 40,000 cps .07v rms: 1 – 10 cps Positive Pulse Rise Time: ½ volt or more/sec.
ACCURACY	±1 count ± stability
STABILITY	0.1% (Normal power line stability) Crystal time base optional.
TIME BASES	0.1 sec. and 1 sec. (10 sec. optional)
READOUT	4 digits (5 digits optional)
DISPLAY TIME	Automatic: Continuously variable 0.1 to 10 seconds. Manual: Until reset
INPUT IMPEDANCE	0.5 megohm and 50 mmfd
PRICE	$1120.00 f.o.b. factory

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2

NEW BOOKS

New Servo Textbook

BASIC FEEDBACK CONTROL SYSTEM DESIGN. C. J. Savant Jr., 418 pp. Published by McGraw-Hill Book Co., Inc., New York, 1958. $9.50.

This text for a first course in servomechanisms apparently was written with senior electrical engineering students in mind, for the major portion of Chapter 2, on obtaining system equations, concerns electric circuit analysis. The author does not strongly support either the classical approach or the transform method, a position that appears untenable in view of the fact that the transform method must be used in all later analysis. He does not introduce the transform calculus in the body of the text, but in a 12-page appendix, which may be indicative of the modern trend in electrical engineering curricula toward reserving transform methods for sophomore or junior analysis courses.

Chapter 3, on steady state errors, naturally discusses poles at the origin and points out their significance, but does not refer to them as "integrations" or give them any special significance. Despite the risk of losing insight, this approach may be satisfactory, since the average student sometimes has difficulty with this concept. The discussion of bandwidth relies on the students' previous knowledge of the concepts of frequency response, and so might be difficult for the non-electrical student.

Chapter 4 introduces the root locus method and the author's basic design philosophy. He believes that the root locus is a simpler concept than analysis in the frequency domain, and that analysis and system stability on the root locus is more readily grasped than on the Nyquist or Bode plots. This appears acceptable, especially since the pole-zero approach is now used in many circuit courses. In Chapter 5, the frequency response methods are introduced. The author feels that these will retain an important place in system design because they provide the actual data on physical systems.

A further advantage of the root locus method, says the author, is the speed with which successive trial designs may be made. This idea is more difficult to justify, since a Bode plot consists simply of straight lines and probably requires less experience to manipulate when an equalizer is to be chosen and properly placed.

System equalization or compensation is discussed in Chapter 6, which

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If you are a qualified engineer or scientist, you are invited to inquire today about positions open in the following fields:
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Lockheed **MISSILE SYSTEMS**

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Shown with the Univac is Dr. J.P. Nash, Information Processing Division Manager, second from right, examining results of a trajectory study with J.P. Ryan, Jr. Left rear, J.B. Potter; right, Byron Zurcher, liaison engineer.

NEW BOOKS

apparently serves as an introduction to the art rather than as a complete discourse (it is only 22 pages). The next three chapters discuss servo components: RC network equalizers, transducers, motors, generators, and gyros. The considerable material on servo components appears warranted, since the student usually finds it as difficult to write the transfer function of a physical system as he does to analyze and synthesize the result. Even familiar rotating machines require the systems point of view when they are to be designed into a control loop. The final chapter introduces some of the problems on nonlinear servo design. Several short appendices on analytic details complete the text.

The book is well organized and appears to be suitable as a text. Problems follow each chapter. There is the unavoidable quota of slips of the pen: the definition of conditional stability (page 24) is inadequate; it is implied on page 16 that it is possible to obtain a transfer function with nonzero initial conditions; but on the whole the book is well built. It will be welcomed by those who prefer the root locus as the basic design tool and frequency response methods as an auxiliary aid for obtaining laboratory test data.

John E. Gibson

Computer Techniques

LOGICAL DESIGN OF DIGITAL COMPUTERS. *Montgomery Phister Jr. Director of Engineering, Thompson-Ramo-Wooldridge Products Inc. 408 pp + xvi. Published by John Wiley & Sons, Inc., New York, 1958. $10.50.*

Intended as a basic text for a one- or two-semester course in computer logic, this book describes and interprets methods rather than hardware, and applies them to a wide variety of design problems. The author assumes no previous computer experience on the part of the reader. Of particular value are his detailed discussions of:

- the Veitch diagram method of simplifying Boolean equations
- the "difference-equation" approach to memory elements
- the Huffman-Moore model of digital systems
- the complete solutions to flip-flop input equations
- a mathematical introduction to Boolean algebra.

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The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed for those desiring more detailed information. 20 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems, 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.25.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—III, March 1958, 16 pp. Includes detailed descriptions of nine machine tool control systems. 40 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. Includes detailed descriptions of ten machine tool control systems. 50 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—I, January 1958, 32 pp. Includes detailed descriptions of twelve machine tool control systems. 60 cents.

Ready Reference Data Files, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 35 cents.

The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

Analysis Instrumentation—II—Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation—I—Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. This reprint consists of the first four articles of the Analysis Instrumentation Series: a general introduction to set the stage, and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors as low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp.

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AI is expanding overseas operations. With 5 foreign reactors already in operation or being built, AI recently signed agreements with ASEA of Sweden, which has offices in 50 countries, and DEMAG of West Germany, with whom AI formed the new company, INTERATOM, in Duisburg, West Germany.

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A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic lagging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

Automatic Machining—A View and a Preview, 24 pp. A quick look at some of the newer techniques that are being used to control machine tools. It deals primarily with recorded-information (numerical) control, discussing ways to automatically furnish machining instructions, ways to drive the tool, or workpiece, and ways to measure position and size. 50 cents.

A Systems Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

Digital Application Series. For those readers who would like to fill out incomplete sets of Application Series articles, the following are available as reprints:

Programming Scientific Calculators —No. 5, May 1956, 6 pp. Describes the three major steps in programming—numerical analysis, drawing the flow diagram, and coding—and illustrates them by a problem solved on the NORC. 25 cents.

Controlling a Process—No. 9, December 1956, 5 pp. Explains why and how the various types of digital computers can be used as process controllers. 25 cents.

Sampled-Data Systems—No. 10, February 1957, 8 pp. Reviews the basic theory of sampled-data system analysis and synthesis, includes a reference list and an example. 25 cents.

Analog-to-Digital Converters—What Ones are Available and How They are Used—No. 11, April 1957, 12 pp. Describes techniques and lists commercial devices. 25 cents.

Fitting the Digital Computer into Process Control—No. 12, June 1957, 8 pp. Outlines a systematic approach to applying digital computers as process controllers and illustrates with a case in point. 25 cents.

The Digital Answer to Data Telemetering—No. 14, August 1957, 8 pp. Discusses the characteristics and requirements of digital-data transmission systems. 25 cents.

Basic Digital Series. For those readers who would like to fill out incomplete sets of Basic Digital articles, the following are available in reprinted form:

Digital Computers Need Logical Design—No. 3, December 1955, 7 pp. Reviews the basic logic functions used in digital computers. 25 cents.

Programming the Computer—No. 12, March 1957, 6 pp. Discusses the fundamentals of digital computer programming. 25 cents.

Checking Techniques for Digital Computers—No. 13, May 1957, 4 pp. Describes the principle of redundancy in checking and error detecting codes. 25 cents.

Tearsheets of most of the other Basic Digital and Digital Application Series articles are also available at a cost of 15 cents per article.

CONTROL BITS

Number of trained Chinese engineers and technicians now working in Red China has reached 800,000, according to the National Economics Commission of China. This is three and a half times the 230,000 estimate reported in 1952.

•

A low-cost electronic data processing system has been developed to handle the recording-keeping needs of the garment industry. Developed by S. J. Capelin Associates, Inc.—specialists in industrial engineering for sewn products—the system uses a Royal-McBee LPG 30 computer and Frieden tape-producing equipment. One advantage claimed: it requires no specially-trained personnel.

•

A linear accelerator atom-smasher two miles long has been proposed by Stanford University. Stanford's Dr. Leonard Schiff told a Senate-House subcommittee on atomic research and development that the university, which has pioneered linear accelerators, proposed building the giant device to conduct atomic transmutation experiments.

•

National Advisory Committee for Aeronautics (NACA) has formed a special committee on space technology. Working groups have been set up to deal with specific aspects of the new field. The groups and their chairmen: Objectives, Dr. James A. Van Allen; Vehicles, Dr. Werhner von Braun; Re-entry, Dr. Milton U. Clauser; Range Launch and Tracking, James R. Dempsey; Instrumentation, Communication and Navigation, Dr. Hendrik W. Bode; Human Factors and Training, Dr. W. Randolph Lovelace.

WHAT'S AHEAD: MEETINGS

APRIL

Instrument Society of America (New Jersey section), Tenth Annual Symposium, Hotel Essex House, Newark, N. J. April 1

American Society of Mechanical Engineers, Fourth IRD Conference, University of Delaware, Newark, Del. April 2-4

Institute of Radio Engineers, 10th Southwestern Conference & Electronics Show, St. Anthony Hotel and Municipal Auditorium, San Antonio, Tex. April 10-12

American Institute of Electrical Engineers, Automatic Techniques Conference, Hotel Statler, Detroit April 14-16

22nd Annual Machine Tool Electrification Forum (sponsored by Westinghouse), Hotel Statler, Buffalo, N. Y. April 22-23

Electronic Components Conference, sponsored by IRE, AIEE, Ambassador Hotel, Los Angeles April 22-24

MAY

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Institute of Radio Engineers, National Aeronautical and Navigational Electronics Conference, Hotel Biltmore, Dayton, O. May 12-14

Instrument Society of America, National Conference on Power Systems Instrumentation and Control, New York May 21-23

JUNE

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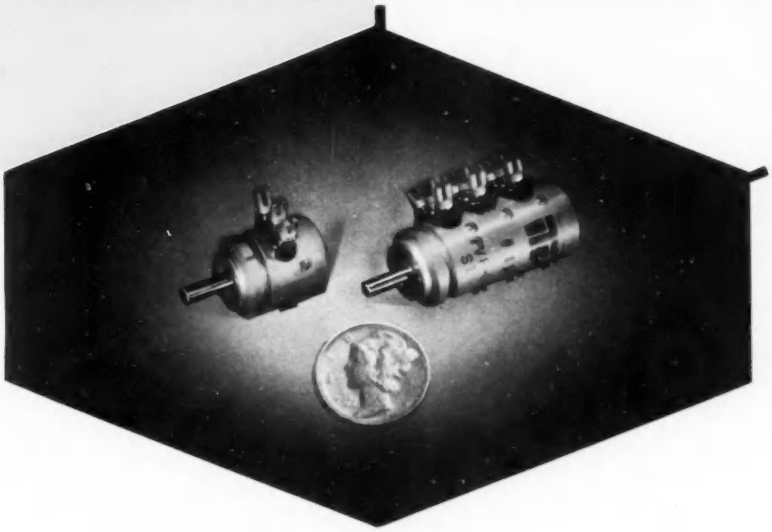

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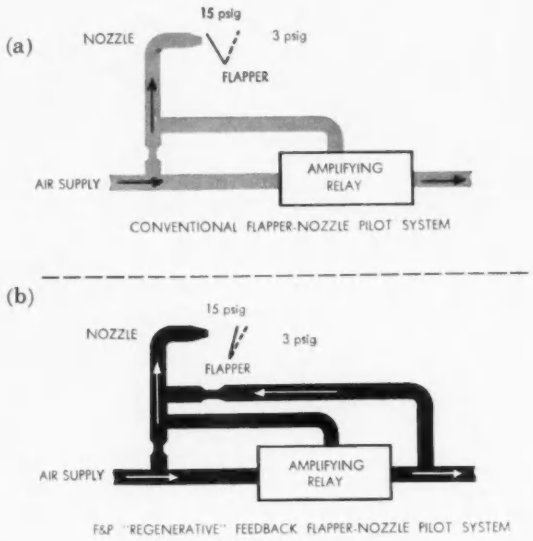
the most impressive fact about regenerative feedback may well be its surprising simplicity. The entire F_R circuit comprises a single restricted air passage. Yet this one addition is responsible for substantially increasing pilot gain and improving both static and dynamic performance. Most important, it permits these improvements even with highly desirable non-bleed type amplifying relays.



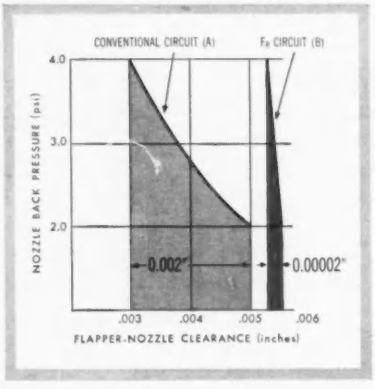
REGENERATIVE FEEDBACK . . .

new factor in pneumatic control

Conventional nozzle pilot systems—like the one shown (a) above—directly convert a change in process-set point relationship to a related change in output pressure. Any change in the relationship of process value and control set point is immediately reflected in the new position of a post, plate, or flapper situated in front of the pilot nozzle. With each change in clearance, nozzle back pressure varies proportionately. Changes in nozzle back pressure control output pressure of the amplifying relay. This simple and effective pilot design is used today in just about every pneumatic controller, including stacked diaphragm or coplanar bellows force-balance designs, and motion-balance types.

motion-balance versus force-balance

Unfortunately, early motion-balance controllers did not make the best possible use of this nozzle-pilot circuit. Non-bleed relays provided insufficient gain for most uses. Bleed-type relays offered increased gain, but at the expense of less desirable dynamics and air consumption. As a result, the trend in plug-in and field mounted controllers switched to stacked diaphragm force-balance designs. Despite their inherent inability to maintain long term calibration, they were undoubtedly the most popular choice over a period of several years. But it is interesting to note that even at the height of stacked-diaphragm popularity, all the large case control applications were still being solved with motion-balance controllers.



a new look at motion-balance principles

Fischer & Porter's initial goal was a single controller design suitable for plug-in, field mounting, or large case application—pneumatic or mechanical inputs. The decision to design on the basis of motion-balance principles was arrived at after considerable study and debate. Well-grounded in the short-comings of available controllers, F & P engineers conducted a fresh evaluation of all principles. The result was the pneumatic application of a concept common for years in electronics . . . *positive or regenerative feedback.*

how F_R works

The mechanics of regenerative feedback are illustrated in (b) above. A change in flapper position increases nozzle back pressure and output pressure. Increasing output pressure is then utilized through the regenerative feedback network to increase air flow through the nozzle. Thus, the change in flapper position necessary to change nozzle back pressure by a given quantity is considerably reduced. The immediate result in terms of flapper-nozzle clearance may be seen in the chart above, relating change in flapper-nozzle clearance with nozzle back pressure for conventional and regenerative feedback pilot designs. Notice that only 0.0002 in. of flapper motion is now required as compared to 0.002 in. of motion for conventional pilots—a ten fold basic improvement in pneumatic circuitry.

The effects of regenerative feedback on controller performance are best illustrated with F & P's Series 53P controller. Advantages directly traceable to regenerative feedback include increased pilot gain, improved static and dynamic performance, low air consumption, increased flapper-nozzle clearance, larger nozzle diameter, and as little flapper motion as any other force-balance or motion-balance controller.

To study the importance of regenerative feedback firsthand, contact the F & P field engineer nearest you for a demonstration or evaluation unit. Or, write for Catalog 53P-4000. Fischer & Porter Company, 748 County Line Road, Hatboro, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto, Ontario.

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